A BEHAVIOURAL VIEW OF THE DECISION FOR CAPABILITY INVESTMNETS: THE SOLAR PV INDUSTRY IN TAIWAN

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Summary

This research examines the role of framing in the process of decision-making for new capability investments under conditions of policy and technological uncertainty. I argue that framing can explain the decision to exploit current capabilities, but is not sufficient to explain the decision to explore new capabilities.

This research discriminates between "frames" and "framing" in the investigation: whereas "framing" is the process of constructing the meaning of the decision problem, "frame" refers to a specific perspective adopted by the decision makers. I develop a three-level research design: the industry-level analysis adopts the approach of eliciting heuristics to identify general patterns. The firm-level examines sources of variation and causal complexity by comparative case analysis. The decision-maker level investigates the influence of senior managers' professional experience using a scenario evaluation approach.

Three observations from the case study of Taiwanese solar PV firms: firstly, systematic patterns are found in the process of framing environmental uncertainty and attributing the causes of the decision problem of capability investments. Secondly, whilst differentiated framing exists and corresponds to selective attention; such a difference is not necessarily associated with different choice pattern. Finally, the loosely coupling framing and choices leads to the speculation that the role of deliberate practice, rather than framing has a stronger influence on the decision to explore.

This research illustrates that the capabilities investment decision is not a single event but a complex process. While the stylised psychological principles explain the heuristic judgments, the influencing factors of an organisational decision are interdependent and temporally connected in the decision context. I argue that the problem of framing lies in prohibiting the alterative frame. Therefore exploration needs to be deliberately sought by the specially designed practice. This research

contributes to understanding the relationship between behavioural view of descriptive analysis and prescriptive view of procedural rationality in the decision- making process.

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Chapter 1

Introduction

1.1 Motivations and rationale

How does a firm respond to uncertainty? Strategy scholars have proposed that firms should develop opportunities from uncertainties and invest in new capabilities for future growth (Gary & Prahalad, 1996; Kogut & Kulatilaka, 2001; McGrath, 2010; Teece, 2007). However, studies have identified the problem that *firms often fail to explore new opportunities in response to environmental uncertainty.* Recent strategy literature points to the difficulty of assessing and capturing new opportunities under uncertainty (Gavetti, 2012; Powell, Lovallo, & Fox, 2011; Starbuck, 2009) in addition to the classic issues of uncertainty avoidance and the tendency of favouring exploitation over exploration in the organizational adaptation process (Cyert & March, 1992; Levinthal & March, 1993; March, 1991; March, 2008).

Linking the concept of exploration/exploitation to capability investment decisions

The decision to explore new opportunities is integrated to the concept of exploration. The original distinction of exploration versus exploitation focuses on organizational learning: while exploration includes activities of discovery and experimentation, exploitation can refer to as refinement and efficiency (March, 1991:71). Subsequent studies have applied the concept of exploration and exploitation beyond the scope of organizational learning. In particular, exploration has been associated with a shift to a different technology trajectory, addressing the latent need of emerging customers and

new product development (Almahendra & Ambos, 2015; Benner & Tushman, 2003; Danneels, 2002; Rosenkopf & Nerkar, 2001). The underlying idea of exploration highlights the spirit of investing in something new with uncertain prospect. This notion includes the decision to invest in new capabilities (Kogut & Kulatilaka, 2001; March, 1991; March, 2008). In this thesis I define exploration as the decision to "invest in new capabilities"; whereas exploitation corresponds with the decision to invest in existing capabilities. I am interested in investigating firms' strategic investment decisions; specifically the timing and level of investments on technology platform and product development. These decisions can be regarded as capability investments because they involve competence building for capturing opportunities from external environmental uncertainty. In this research, the definition of capabilities is used interchangeably with the definition of resources, referring to "the tangible and intangible assets firms use to develop and implement their strategies" (Ray, Barney, & Muhanna, 2004:24). Therefore the focus is on the investment in capabilities rather than the capabilities per se.

The condition of uncertainty and the assumption of rational actors

Strategy scholars seek to explain the problem of *"why do some firms fail to explore new opportunities in response to uncertainty"* with different conceptual lenses. There are three main approaches: First, from the perspective of external environmental assessment, it is suggested that firms should formulate their strategy based on the environmental and industry analysis (Porter, 1980). However, there are three major criticisms of this approach: (1) the condition of uncertainty questions the static analysis of industry structure; (2) a lack of consideration of firms' heterogeneity in resources (Barney, Ketchen, & Wright, 2011; Teece, Pisano, & Shuen, 1997); and (3)

the assumption of rational actors.

Second, the resources-based view (RBV) addresses the issue of a lack of consideration of firms' heterogeneity with the emphasis of inward thinking of firm resources. From the perspective of the RBV tradition, the problem of why firms fail to explore new opportunities can be explained by their resources constraints. While some scholars have critiqued whether RBV addresses the condition of uncertainty and the role of managers (Kraaijenbrink, Spender, & Groen, 2009), refined RBV and Dynamic Capabilities (DC) tackle this problem by proposing the concept of "fitness" between firms' external environment and internal resources and capabilities. In particular, DC scholars have emphasized "managerial capabilities" and senior managers' role in driving "entrepreneurial fitness" to explore new opportunities under uncertainty (Helfat et al., 2007; Teece, 2007; Teece, 2012). Following the same RBV rationale, the problem of why firms fail to explore under uncertainty can be explained by their lack of dynamic capabilities. In addition to the criticism of "recurring regression" in explaining firms' behaviour, there is an issue of assuming management discretion in the process of strategic decision-making. The assumption of rational actors is not addressed (Gavetti, Levinthal, & Ocasio, 2007; Kraaijenbrink et al., 2009).

Finally, the emphasis of managers' role in DC has been reflected in the trend of incorporating the Top Management Team (TMT) perspective and particularly the management cognition view in DC. Research from the management cognition school highlights managers' role in "shaping the strategic choices and related processes" (Kaplan, 2011:665). Therefore, from the perspective of management cognition school, the problem that firms fail to explore new opportunities can be explained by

management cognition issues rather than resources and capabilities constraints (Tripsas & Gavett, 2000). In addressing the condition of uncertainty, the management cognition school suggests that environment is "endogenous" and emphasises managers' interpretation and sense-making of the uncertain environment (Kaplan, 2011:667, 677; Milliken, 1990). Following this tradition, subsequent management cognition studies have focused on managers' cognitive schema, mental representation, and attention focus interacting with organizational factors (Cho & Hambrick, 2006; Eggers & Kaplan, 2008; Gary & Wood, 2011; Gregoire, Barr, & Shepherd, 2009).

This research is positioned in the management cognition school's analytical direction in tackling the problem -"why do some firms fail to explore new opportunities in response to uncertainty". Yet, through incorporating the analysis drawing from behavioural decision perspectives[1], this research differs with the main stream investigation of management cognition school in two aspects: the first is that it explicitly addresses the rationality assumption. The second is that it emphasises senior managers' pattern of judgement rather than representation of cognitive schema.

The behavioural decision perspectives

The behavioural decision school began with a research program on "heuristics and biases" by Amos Tversky and Daniel Kahneman in 1974 (Gilovich, Griffin, & Kahneman, 2002; Tversky & Kahneman, 1974). Drawing on the psychology of perception, Tversky and Kahneman firstly explored the problem of *judgment under uncertainty* in their early studies. The key idea is that decision makers use the rule of

[1] In this research, behavioural decision perspectives are narrowly defined as belonging to the school of behavioural economics initiated by Tversky and Kahneman.

thumb or cues accessible in the decision context when making judgments. While these judgments may not necessarily be irrational, decision makers are usually not aware of the use of heuristics; thus biases arise in the judgment and decision process. Tversky and Kahneman suggest that the behaviour of heuristic judgment is systematic among decision makers and that such a pattern can be illustrated by general heuristics and the associated biases (Tversky & Kahneman, 1974, 1981).

Later, Tversky and Kahneman proposed the theory of choices, specifically in relation to the framing effect. The definition of "*framing*" is that the interpretation of the decision problem can influence judgment and decisions. Beyond this general concept, the key idea of the *framing effect* is that decision makers' judgment and choices are usually susceptible to certain perspectives. In their experiments, Tverky and Kahneman demonstrated that different assessments of the choices were invoked when the decision problem was framed in a different way. Moreover, their findings suggested that decision makers usually passively accepted the assigned decision frame in their evaluation of the choices.

On the theoretical basis of *heuristics* and *framing*, behavioural decision scholars challenge a number of commonly-held *rationality assumptions*: specifically, the *dominance* and *invariance* principles in the normative decision utility model which are usually assumed in the strategy studies. First, the dominance principle assumes that decision makers would aim at the optimal choice and maximize the expected decision utility with incentives. Behavioural decision scholars argue that the dominant option is usually guided by a *frame* and is not necessarily the optimal choice. Second, the invariance principle assumes preference consistency in the decision making process. But behavioural decision theory's reference-dependent *framing* effect in

choices demonstrates that decision makers' choices are affected by simply changing the description of the decision problems. Thus the rational principle of invariance is questioned (Kahneman, 2000b; Tversky & Kahneman, 1986). In questioning these rationality assumptions, behavioural decision theory emphasises that the decision utility is influenced by the experience, which is "triggered by the emotion of change" (Kahneman, 2003b).

Behavioural decision scholars argue that the violation of the rationality assumption is rooted in the psychological mechanism. The deviations from the rational decision model are "common and systematic" and "cannot be treated as random errors" (Kahneman, 2000b; Tversky & Kahneman, 1986). Despite the criticism of detaching business reality in the experimental approach employed by behavioural decision theory, the application of heuristic, framing and the associated biases have been found in numerous examples of real-world investment decisions. Such "persistence of cognitive biases" highlights the merit of the behavioural decision perspectives in providing stylized principles for predicting decision behaviour (Powell et al., 2011:1378).

The focus of decision problem interpretation- integrating the behavioural and organizational decision perspectives

With the aims of providing nuanced understanding of the "interpretative (decision) process" (Kaplan, 2011; Powell et al., 2011) and assessing the pattern of judgment under uncertainty, I choose to investigate this problem "*Why firms fail to explore new opportunities in response to environmental uncertainty"* from the perspective of decision-making and examine the factors influencing the judgment and decision

process.

The understanding of decision problem is central in the board area of management and decision studies. While this research draws from the theoretical perspectives of behavioural decision theory, it is imperative to integrate key concepts from organizational decision theory because the research problem concerns firms' decision-making process.

The behavioural decision and organizational decision perspectives[2] both share the same root – that of bounded rationality – from Herbert Simon (Gavetti et al., 2007; Gilovich et al., 2002; Kahneman, 2003b). The central idea of *selective attention* that was developed from Simon's bounded rationality signifies the divergence of the investigation focus between the behavioural and organizational decision perspectives: while behavioural decision perspectives emphasize the underlying psychological mechanism common in the judgment and decision process, the organizational decision perspectives concern the effect of selective attention resulting from the decision makers' characteristics particularly the identities and interests, as well as the organisational decision context (March & Simon, 1958; Ocasio, 1997; Simon, 1996a).

From the behavioural decision perspectives, the "selective attention" and different salience of the environmental stimulus are described as the "determinants of differential "accessibility"[3](Kahneman, 2003b:699). The discussion of differential accessibility concerns more abstract aspects such as "similarities", "causal propensity"

[2] Here the organizational decision perspectives refer to the classic and foundational works from Simon and March.

[3] The concept of accessibility refers to "the ease (or) efforts with which a mental content comes to mind." (Kahneman 2003).

and “surprisingness” in influencing the different accessibility of “thoughts” in the judgment and decision process (Kahneman, 2003b:701).

From the organizational decision perspective, selective attention is defined as the process of “channelizing the stimuli” (Simon, 1996a). According to organizational decision scholars, selective attention is influenced by specific organizational decision context and is driven by organizational identification mechanism such as shared goals and expectations. Senior managers’ professional roles and experience may also influence selective attention, of which the aspect of information processing is emphasized (March & Simon, 1958; Ocasio, 1997; Simon, 1996a). These factors of organizational decision context and decision makers’ attributes are the focus of investigation in the organizational decision school. The behavioural decision school does acknowledge the potential influence of such factors but little inspection on this.

Both the behavioural and organizational decision perspectives are important in investigating the process of decision problem interpretation – to examine whether the prediction of the systematic pattern derived from the common psychological mechanism would hold, or the heterogeneous pattern would be found and be better explained by differentiated framing among decision makers.

The integrative theoretical view and analytical approach, which draws on the behavioural and organizational decision schools, not only provides a more nuanced understanding of the decision problem interpretation, but also addresses the recent development found in behavioural and organizational decision perspectives. First, organizational decision scholars have called for “reconceptualising bounded rationality” through examining individuals’ choice model and the linkage between

multiple factors and processes (Gavetti et al., 2007:531-532). Second, both behavioural and organisational decision perspectives have suggested the importance of providing insights for prescriptive approach from the descriptive view of decision process: while organizational decision scholars advocate "the latent normative value of organizational decision theory" as opposed to its "claims for descriptive realism"(Gavetti et al., 2007:533), behavioural decision scholars call for producing "framework that integrate psychology and strategy practices" (Powell et al., 2011:1370).

Research question

I have discussed earlier that in addressing the problem "why do some firms fail to explore new opportunities in response to uncertainty", this research focuses on the decision –making process. The investigation of decision–making focuses on the process of constructing the meaning of the decision problem. Such a concept of decision problem interpretation is central in both behavioural and organizational decision theory.

The use of the term "framing" as the central investigation theme

From the organizational decision perspectives, the process of interpreting decision problem refers to "information processing" or the structuring of the attention (Gavetti et al., 2007:537; March & Simon, 1958; Ocasio, 1997; Simon, 1996a). The behavioural decision perspectives in particular focus on how the interpretation of the decision problem influences influence the judgment and decision process (Kahneman, 2003a; Tversky & Kahneman, 1981). In this research, I use the broad definition of the

term "*framing*" - referring to the general concept of decision problem interpretation – as the central theme of the investigation. Therefore, from the organization decision perspective, the term "framing" suggests the process of structuring attention focus and the effect of selective attention. Drawing on the behavioural decision perspectives, the term "framing" encompasses the concept of heuristics judgment and the framing effect on reference –dependent evaluation.

In fact, the term "framing" as applied in behavioural decision theory of framing effect combines two different concepts – "*framing*" and "*frames*" (Kahneman & Tversky, 2000:xiv). The former refers to the process of constructing the meaning of the decision problem, while the latter refers to the specific decision logic or perspective adopted by the decision makers. In behavioural decision experiments, the treatment of the single term is used because the manipulated changing frames (assigned by the researcher) are employed to examine decision makers' framing process. However, in the investigation of the real-world decision problem, the distinction between framing and frames can be critical for two reasons: one is that there are no assigned decision frames in the real setting, and the other is that decision makers may use different frames in the framing process for more complex decision problems.

While I adopt the same treatment of the single term "framing" in the research question, a key idea of this research is to examine the two constructs of "framing" and "frames", and their relative effect on judgment and decisions. Therefore, while this research investigates the dynamics of the framing process, it also looks into what the prevailing frame is and how the decision frame is formed.

The research questions

This research focuses on examining the central theme of framing in the decision process. The treatment of the role of framing in behavioural and organizational decision studies usually assumes a causality connection between framing and choices. However, such a linkage may not always be held under the organizational decision complex. More recent organizational decision studies call for revisiting the concept of "*loosely coupling*", in which the role of contingency in timing and context is stressed in the organizational decision making[4] (Gavetti et al., 2007:529; March, 1994).The concept of loosely coupled framing and choices questions the basic assumption of management cognition studies that "strategic decision process constitutes the decision behaviour" (Thomas, Clark, & Gioia, 1993:247). This concept of loose coupling has two implications for investigating the role of framing in this research: the first is that, it implies that decision makers may use different "frames" in the "framing" process. The second is the possibility that "framing" may not necessarily explain certain judgement and decision behaviour.

Therefore, drawing on the central theme of understanding the role of decision problem interpretation in the judgment and decision process, the first research question is to examine to what extent the concept of framing explains firms' decision to invest in new capabilities. The first research question asks: "***What is the role of framing in the decision-making process for new capability investments***?" Then, incorporating behavioural decision theory's analysis on the common structural elements in the decision environment with organizational decision theory's emphasis on decision makers' specific characteristics and their situated decision context, the

[4] March describes this phenomenon mainly as the result of collective decision behaviours in the organization, and emphasizes the loose coupling of framing and actions. Here in this research, it focuses on the loose coupling of framing and choices.

second research question asks: "***What factors may influence the role of framing in such process?***"

1.2 The Research plan

The development of the research design is a central part of this thesis. There are two issues in need to be resolved here: the first is that the complexity of the concept of "framing" makes it difficult to measure in a single construct. The second is that the examination of the concept of "frames" needs to consider different influences in the decision context. Therefore, a new element of this research is to develop a three-level research design to address the interaction of the framing process and the influences of the decision frames.

The multilevel analytical approach

The investigation of decision behaviour is generally considered to be focused on the micro level analysis. Yet the research questions here actually encompass multi- level inquiry. First, the capability investment decisions are the firm-level strategic decisions. Second, firms' reactions to environmental uncertainty are inevitably linked with the macro (and meso) industry environment analysis. Finally, senior managers are those who made the decisions. Therefore this research employs the concept of multi-level analysis. The approach of multi-level analysis corresponds with the recent call for "micro-foundation thinking": the idea of micro-foundational thinking argues that as "different findings may result from different level of analysis", the investigation should emphasises the way "levels of analysis differ and relate to each other". Thus both the multi-level approach and micro-foundational thinking emphasises the investigation of "causal link in process chain" across levels of analysis. Such multi-level of analysis addresses the macro-micro bridge and is more in line with the concerns of practical predictions (Aguinis, Boyd, Pierce, & Short, 2011:397;

Devinney, 2013:82-83).

In the multilevel analysis, the concepts of "examining interrelationship between individual's cognitive constrain and structural mechanism allocating attention within the organization… and cross- level linkages" have been suggested in organizational decision studies (Gavetti et al., 2007:531-532; Ocasio, 1997). This multilevel framework has been proposed in the areas of complex judgment and entrepreneurial decision-making in recent empirical works (Priem, Walters, & Li, 2010; Shepherd, 2011).

This research uses the multi-level analysis to examine multiple influences across levels and addresses the integrative view of behavioural and organizational schools in analyzing decision behaviours. This operating principle guides the research design and investigation approach in the empirical section.

The first level of the research design examines the influences of industry incidents and structural elements common in these firms' external environment. In answering the research question: "*What is the role of framing in the decision-making process for new capability investments?*", the concept of *framing* at the first level of the research design draws on behavioural decision theory of *heuristic judgement* and focuses on examining the process of framing external environmental uncertainty**.**

The second level of the research design examines the firm level, in which differences in capability investment and selective attention patterns are assessed. In answering the research question: "*What is the role of framing in the decision-making process for new capability investments?*" the second level of the research design focuses on

examining the firm-specific pattern of capability investments and decision problem interpretation. This level of research design also addresses the second research question *"What factors may influence the role of framing in such process?"* as it investigates how organizational factors influence framing and decisions at the firm level. Different from the behavioural decision theory of *framing*, here the definition of framing employs the general concept of decision problem interpretation. Specifically, the concept of framing in the second level of research design draws on the concepts of *selective attention* and *attention-based view* from the organizational decision perspective.

The third level of the research design looks into the decision-maker level and examines the relative influences from senior managers' professional experience, the organization, and industry context on the process of interpreting decision problem for capability investments. In answering the research questions: "*What is the role of framing in the decision-making process for new capability investments?*", and *"What factors may influence the role of framing in such process?"* the third level of the research design draws on the organizational decision perspectives of selective attention and incorporates the view from the behavioural decision perspectives of heuristics judgement.

The structure of the thesis

The thesis is organized as follows:

Chapter 2 is the theoretical chapter. Chapter 2 discusses the key concepts of heuristics and framing in behavioural decision theory, followed by reviewing the concepts of

selective attention and attention-based view in organizational decision theory. Then the concept of the two-system cognitive process is introduced to illustrate the different focuses between the behavioural and organizational decision perspectives.

Chapter 3 is the methodology chapter. Chapter 3 starts with reviewing strengths and limitations of various approaches to decision studies, followed by discussing the rationale of employing case study approach in this research. Then Chapter 3 presents the three-level research design and the data collection and analysis approach of this research.

Chapter 4, 5 and 6 are the empirical chapters. Chapter 4 investigates the process of framing external environmental uncertainty in the context of the five Taiwanese PV firms. Chapter 5 examines selective attention at the firm level. The investigation emphasises comparative analysis of the three c-Si PV firms. Chapter 6 focuses on selective attention at the decision maker level with the empirical investigation of senior R&D and finance managers from the five case firms.

Chapter 7 is the concluding chapter. Firstly, drawing insights from previous empirical findings, Chapter 7 discusses the potential role of deliberate practice in influencing the decision to invest in new capabilities. The theoretical concept of deliberate practice is derived from the prescriptive view of behavioural and organizational decision perspectives. The discussion is illustrated with the empirical finding from the case of *Greenchild*. Secondly, Chapter 7 summarizes the empirical investigations from Chapters 4, 5 and 6. An integrated discussion of the findings is organized in two parts, comprising the role of framing and the role of deliberate practice. This chapter then proposes two perspectives of implications for the domain of strategic decision

making: the application of the rational decision model, and the triggering mechanism for exploration. Finally, limitations of this thesis and directions for future research are discussed**.**

Chapter 2

Behavioural and Organizational Decision Perspectives

Introduction

Chapter 2 reviews key theoretical concepts in behavioural and organizational decision perspectives.

Section 2.1 discusses key propositions in behavioural decision theory, specifically the concepts of heuristics and framing in the judgment and decision process[5]. Firstly, the inherent use of heuristics has been signified as the foundation of behavioural decision theory in predicting common biases and judgment pattern. Secondly, the core concept of framing, particularly the narrow framing effect explains the influence of decision problem interpretation in the decision-making process. Two elements are distinguished in the framing effect: one is "framing", the process of constructing the meaning of the decision problem. The other is the "decision frame", the specific logic or perspective adopted by the decision makers.

Section 2.2 reviews the concepts in organizational decision perspectives, specifically selective attention and attention-based view. Different from the proposition of the homogenous pattern predicted by behavioural decision perspectives, the organizational decision concept of selective attention stresses the heterogeneous pattern resulting from the choice context and decision makers' characteristics. The attention-based view proposes that firms' behaviour can be explained by the issues on

[5] Basically, behavioural decision scholars consider that the process for judgments and decisions share similar psychological principles (Kahneman 2003).

which they focus their attention; and that firm resources, organizational structure and Top Management Team's characteristics may influence firms' attention structure.

Section 2.3 introduces the concept of the two-System view adopted by behavioural decision research: the automatic System 1 and the controlled System 2 cognitive process. It discusses how the two-system view may illuminate the different emphases and investigation direction of the behavioural and organizational decision perspectives. With the focus on the automatic System 1 process, behavioural decision perspectives suggest a common difficulty in developing alternative logic from the controlled System 2 process. Viewing decision as problem-solving in the System 2 process, organizational decision perspectives focus on factors that may distinguish the patterns among decision makers.

2.1 Behavioural decision perspectives

This section reviews the behavioural decision theory of heuristics and framing. Core concepts and theoretical claims of heuristics and framing are summarized in **Table 2.1**

Table 2.1 Key concepts of heuristics and framing

	Core psychological concept	Key theoretical claims	Key applications and experiments
Heuristics	Principle or cues for judgement - the pattern matching and memory retrieval process.	*Representative and Availability heuristics :* both heuristics apply the *Attribute substitution* model . *Anchoring* heuristics : estimate from the initial value (given target)	Biases associated with each heuristic. Representative : the neglect of prior probabilities and validity. Availability : the ease of constructing the instances. Original experiments of both heuristics are based on the responses of frequency judgments (Tversky and Kahneman 1974). The Linda problem : judgement of similarities overrides the logical probability judgement (Tversky and Kahneman 1982). Anchoring : the insufficient adjustment or being influenced by the external target. The experiments are based on the estimate of a subject's value with a given reference target (Tversky and Kahneman 1974)
		Affect heuristics: the role of emotion in the judgement and decision process	Relevant to the development of *experience effect* - the emotion of change, the sense of losses and gains sense of loss and the feeling of control
Framing	Reference-dependent assessment of the decision outcome - decision utility is based on evaluating the change relative to the reference point	Framing effect : the invariance principle in the rational decision model is violated. Different decision frames "evoke different evaluation"	Different decision frames "evoke different evaluation" (Kahneman 2003). The Asian disease problem (Tversky and Kahneman 1981) and the surgery and the radiation therapy (McNeil, Pauker, Sox andTversky1982) : the "survival decision frame" - the effect of different descriptions on the certainty of survival or death.
		Prospect theory : loss aversion. The cumulative prospect theory: adding the principle of *diminishing sensitivity* - "the impact of a change diminishes with the distance from the reference point" (Tversky & Kahneman 2000 : 50)	The gain/loss decision frame: risk seeking in the prospect of losses - the gambling problem experiments (Kahneman & Tversky 1979). Cumulative *prospect theory*: Risk seeking in the prospect of low probability of gains and risk averse in the prospect of low probability of losses. The gambling experiments include both risky and uncertain prospects (Tversky & Kahneman 2000).
			Judgement under uncertain prospects: people are less sensitive to uncertain than to risky prospect. The game-betting experiment: add different sources of uncertainty (Tversky & Fox 2000). The *competence hypothesis* : people prefer to bet on their competent areas. The experiment of football fans and politics- savvy people(Heather & Tversky 1991).
			Narrow framing: the isolating effect in evaluating investment projects (Kahneman & Lovallo 1993).

Heuristics

The inherent use of heuristics in decision-making under uncertainty is first explored in the research program of behavioural decision theory (Gilovich et al., 2002; Kahneman, 2003a; Kahneman, 2003b; Tversky & Kahneman, 1974). According to Tversky and Kahneman, heuristics are described as "principles, processes or sources of cues for judgment" (Kahneman, 2003b: 707; Tversky & Kahneman, 1974). The heuristics judgment process applies the psychological mechanism of perception (Kahneman, 2003b), and provides the foundation of behavioural decision theory. Following the rule of cognitive ease, heuristics are employed to simplify the complexities of decision-making, particularly under uncertainty (Tversky & Kahneman, 1986). Heuristics are not necessarily irrational or simple; on the contrary, they draw on the process of pattern matching and memory retrieval. Heuristics can be efficient and sometimes yield good or reasonable judgment under certain circumstances (Gilovich et al., 2002; Kahneman & Klein, 2009). However, systematic errors are commonly found in heuristic judgment (Kahneman, 2003a; Tversky & Kahneman, 1986).

There have been challenges regarding the central themes of "heuristics and biases" in behavioural decision theory. One criticism is the applicability of the findings, as the experiments were mainly carried out in laboratory environments. Yet as the research program was inspired by decision biases in the real world, the aim of the research design is to elicit the heuristics by detecting the biases (Gilovich et al., 2002; Kahneman, 2003a; Kahneman, 2003b; Kahneman & Frederick, 2002). In fact, the use of heuristics and the accompanying biases identified by the behavioural research program have been found in the real world, particularly in financial investment and business decisions (Bondt & Thaler, 2002; Kahneman, 2011; Kahneman, Knetsch, &

Thaler, 1991; Teece, 2007). Another critique related to behavioural experiment design is that the research program usually assumes that the accurate decision logic is to be compared with the judgment from the respondents. Scholars have argued that behavioural decision researchers may be in danger of applying the wrong normative or oversimplified models (Stanovich & West, 2002). However, the essence of the research program does not necessarily lie in the assessment of "right" or "wrong". When compared with predictions from the rational model, the findings of the behavioural decision model aim to illustrate the limitations in developing alternative heuristics and frames in the decision process.

Three general heuristics

Tversky and Kahneman identify three general heuristics: "representativeness", "availability" (of instances or scenarios), and "anchoring" (and adjustment) (Tversky & Kahneman, 1974. These heuristics may serve as the prediction base to evaluate decision makers' judgment under uncertainty. The "representativeness" heuristic refers to "some probability judgments that are mediated by the assessment of the resemblance" (Kahneman & Frederick, 2002: 49). The "availability" heuristic refers to the judgments being made by "the ease with which instances or associations come to mind" (Schwarz & Vaughn, 2002: 103). Finally, the "anchoring" heuristic is defined as the process of "making estimates by starting from an initial value that is adjusted to yield a final answer" (Schwarz & Vaughn, 2002; Tversky & Kahneman, 1974: 1128). Systematic biases can be categorized and linked to each heuristic. For example, the use of representative heuristics may lead to the neglect of prior probabilities and insensitiveness to predictability and validity. The use of availability heuristics may lead to biases due to the ease of retrieving and constructing instances.

Also, biases arise when the adjustment from an anchor is insufficient, or from the "priming effect" from the target anchor (Chapman & Johnson, 2002; Kahneman, 2011; Tversky & Kahneman, 1974).

Attribute substitution

In Tversky and Kahneman's early research, the uncertainty of the decision context is illustrated as the condition for the use of heuristics and the occurrence of the related judgment biases (Tversky & Kahneman, 1974). The model of "attribute substitution" introduces the idea that the occurrence of the heuristic judgment may lie beyond this uncertain context. (Kahneman, 2003a; Kahneman, 2003b; Kahneman & Frederick, 2002). The definition of "attribute substitution" claims that "judgment is mediated by heuristics when the individual assesses a specific target attribute by substituting a related heuristic attribute that comes more readily to mind" (Kahneman, 2003b: 707). In other words, the model of attribute substitution proposes a common process for heuristics: when faced with a complex judgment/decision task, people may answer an easier question instead (Kahneman, 2011). In particular, attribute substitution can be applied to the representative and availability heuristics (Kahneman, 2003a; Kahneman & Frederick, 2002).

Affect heuristic

The affect heuristic was identified later on, in order to highlight the role of emotion in the judgment and decision process. While the early three heuristics focus on the limitations of cognitive capacity, the affect heuristic emphasizes the influence of evaluative attributes (Kahneman, 2003b). For example, the affect (liking or disliking)

can be linked to the sense of loss or gain that may influence decision makers' risk attitude in judgment and choices. Thus decision makers' evaluations of decisions are based on the experienced utility and not necessarily consistent with the preference predicted by the normative decision utility theory. The development of affect heuristics signifies another central theme of the behavioural decision theory – the framing effect and the prospect theory.

Framing

In discussing how choices are affected by the interpretation of the decision problem, Tversky and Kahneman introduce the "framing effect" (Kahneman & Tversky, 2000: xi; Tversky & Kahneman, 1981, 1986), in which the violation of the invariance assumption in the rational decision model is demonstrated (Kahneman, 2003a; Kahneman, 2003b; Tversky & Kahneman, 1981, 1986). The "decision frame" is defined as "decision makers' conception of the act, outcomes and contingencies associated with a particular choice." (Tversky & Kahneman, 1981: 453). The original experiments of framing effects show that the preferences of the choices are altered when the decision problems are framed in different ways. In other words, different frames of the decision problem may "evoke different associations and evaluations" (Kahneman, 2003b: 6), and thus influence choices. In an example of the choice between different rescue programs prepared to deal with the outbreak of a disease, Kahneman and Tversky found that the program relating the certainty of the number of people saved is "disproportionally attractive" compared to the other program that describes the certainty of the possible number of deaths. In another experiment about changing the description of the statistical outcome in the survival/mortality frame, scholars found that the "90% short-term survival rate" of radiation therapy is highly

preferable to the "10% immediate mortality rate" of surgery. The results hold for patients as well as physicians (Kahneman, 2003b: 702).

In the behavioural decision school's experiments, the "wealth frame" or the "survival frame" is the most commonly assigned frame in terms of choices (Kahneman, 2003b; Tversky & Kahneman, 1981). While these frames may not always be relevant to all decision problems, the concept can be applied in examining the "frame" employed in a specific decision context. For example, in the context of the PV industry, a similar proposition would be the profit or loss frame in evaluating the investment projects. Thus the 60% chance of earning a 3% margin in the short-term can be preferable to the 40% chance of earning nothing (or taking a loss) in the short-term, but gaining a 6% margin in the long-term.

Prospect theory

The framing of the decision outcome is reference-dependent. In the prospect theory**,** Tversky and Kahneman argue that the determinant of a decision utility is not necessarily based on the assessment of the "final state of the assets" (as emphasized in the normative decision utility theory) (Kahneman, 2003a: 1457), but rather is based on the change of wealth according to the evaluation relative to the "reference point" (Kahneman, 2003b; Kahneman & Tversky, 1979; Tversky & Kahneman, 1981). In other words, it is the comparison between the new level of stimulus and the current "adaptation level", rather than the "new level of stimulation" that determines the decision utility (Kahneman, 2003b: 704).

Decision makers tend to "attach" the value of gains or losses in the decision utility

with the reference point of the status quo (Kahneman, 2000b; Kahneman, 2011). The prospect of gains is referred to the outcome that is better than the reference point, and the prospect of losses is referred to the outcome that is worse than the reference point. In elaborating how the framing of gain or loss prospects influences choices, Tversky and Kahaneman suggest two principles: diminishing sensitivity (defined as "marginal impact diminishes with distance"[6] (Tversky & Fox, 2000: 95) to the evaluation of changes in wealth, and loss aversion – where the response to losses is much greater than the response to gains (Kahneman, 2003b; Kahneman, 2011; Kahneman & Tversky, 1979; Tversky & Kahneman, 1981).

The original model in prospect theory suggests that decision makers are risk-averse at the prospect of gain and risk-seeking at the prospect of loss (Kahneman & Tversky, 1979; Tversky & Kahneman, 1981). In an experiment dealing with gambling scenarios, scholars found that people would reject the gamble when there was an equal chance to win or lose; the results stayed the same even with the increase of the total wealth level. Then the experiment showed that people became more willing to bet, until "the prize of the possible win was at least twice the size of the possible loss" (Kahneman, 2003b: 704). In another gambling experiment, Tversky and Kahneman found that people's preferences changed when a description of a certainty of loss was added to the gambling scenario. Under this prospect of loss, people would bet on an equal chance to win or lose, even when the amount of the possible loss was much higher than the prize of the possible win (Kahneman, 2003a; Kahneman, 2003b).

Therefore Kahneman argues that prospect theory reflects the experience of "the

[6] The concept of "diminishing sensitivity" is further discussed in the judgment of uncertainty and risky prospects.

transition from one state to another". The emotion of such short-term decision outcomes contrasts with the evaluation of the "final state interpretation" of the decision utility, as suggested by the rational decision models (Kahneman, 2003a: 1457).

The concepts of reference dependency and loss aversion in prospect theory can also be applied to observations in the real world. For example, scholars found that the "actual out-of-pocket losses" are usually weighted with more importance than losses of opportunity. Moreover, as the reference point is usually the status quo, it suggests that the evaluation of investment projects is based on comparisons with the current state and that "disadvantages loom larger than advantages" (Kahneman, 2003a: 1458). This explains the notion that investing in current capabilities is usually preferred, because exploitation has the advantage of sooner and closer returns than exploration in the organization (March, 2008).

Later, in the "cumulative prospect theory", Tversky and Kahneman include both risky and uncertain prospects in the gambling experiment. Four distinct patterns are identified in this advanced prospect theory: in addition to the risk-averse behaviour at the prospect of gain, and risk-seeking behaviour at the prospect of loss (as observed in the original prospect theory)[7] they found two different patterns of the uncertain prospect. The first was that decision makers tend to be risk-averse at the prospect of loss with low probability, because they fear larger losses. The second was that decision makers tend to be risk-seeking at the prospect of a low probability of gain, because they hope for larger gains (Kahneman, 2011; Kahneman & Tversky, 1992).

[7] In the experiments, risky prospects are defined as prospects with high probability whereas uncertain prospects are defined as those with low probability.

For example, some PV firms may still invest in capacity expansion despite their knowledge of policy and market uncertainty. Such risk-seeking behaviour can be viewed as the firms' anticipation of grabbing larger gains from the uncertain prospect.

Judgment for uncertain prospects

Extending the principle of "diminishing sensitivity" in the judgment of probability, behavioural decision scholars further distinguish the judgment and decision weights between risky and uncertain prospects. Following Knight's definition of risk and uncertainty (risk is associated with known probability, whereas the probability of uncertainty is unknown) (Knight, 1971), the behavioural decision scholars propose that decision makers are less sensitive to the uncertain than to the risky prospect. When the two reference points – certainty and impossibility – are considered in the concept of diminishing sensitivity, it is suggested that decision makers judge the event with greater weight when it is turning from impossibility to possibility (or from possibility to certainty), than when the event simply turns from more to less probable (Tversky & Fox, 2000).

Following this concept, another implication for the decision under uncertainty is the "unpacking effect". Behavioural decision scholars found that decision makers weight the attractiveness of a prospect higher when the description of an event is unpacked into relevant sub-events. Moreover, it is the role of preference or belief to influence the judgment and decision under uncertainty. While the observation of ambiguity aversion states that decision makers "prefer to bet on known probability rather than unknown probability", behavioural decision scholars further demonstrate the "competence hypothesis", that states decision makers have different preferences over

sources of uncertainty (Fox & Tversky, 2000: 140). They prefer to bet on uncertainty events in which they have areas of expertise or belief in their own competence than bet on events in which they feel less knowledgeable or competent, even when the chance of the former can be more ambiguous than the latter (Fox & Tversky, 2000; Heath & Tversky, 1991; Tversky & Fox, 2000).

Narrow framing

Considering the central role of framing in the judgment and decision process, an important application of framing effects is the notion of "narrow framing". The narrow framing effect suggests that decision makers may not consider all the relevant consequences, opportunities and risks when making choices (Kahneman, 2003b), because their choices are influenced by the perspective effect from the decision frame (Tversky & Kahneman, 1986). The influence of the prevailing frame of gains/losses described in prospect theory is an example of narrow framing in evaluating investment projects (Kahneman, 2003b). On the one hand, the tendency to overweight small risks is coincided with the observation of the attitude of the risk-averse towards small-sized investment projects. On the other hand, risk-seeking behaviour towards large investment projects can be affected by over-optimistic forecasts resulting from the overweighting of the likelihood of gains. Narrow framing implies that decision makers tend to isolate the current decision problem from other pending choice issues or future opportunities - the isolating effect in evaluating investment projects (Kahneman, 2003b; Kahneman & Lovallo, 1993).

Framing and frames

In Tversky and Kahneman's theory of framing effect, the terms "framing" and "frame" were similarly applied to account for the interpretation of decision issues. Yet Kahneman recognizes the fact that there is a distinction between framing and frame. *Frame* originally is labelled as the manipulated account of decision problems in the behavioural experiments. It can be extended to refer to decision logic or perspectives adopted by the decision makers. *Framing* is the process of constructing the interpretation of the decision problem. The treatment of the single term may help in explaining the concept of framing in behavioural decision theory (Kahneman & Tversky, 2000: xiv). For example, the investigated frame is simplified as loss and gain in monetary terms in the behavioural experiments. However, the distinction between framing and frame can be critical in examining the decision problems in real business environments. Also, decision makers may use different frames in the framing process for more complex decision problems.

The "passive acceptance" of the decision frame (Kahneman, 2003b) is the key assumption in describing vulnerability to framing effects. Further, decision makers may not necessarily be aware of the alternative frames for the evaluation of the relative effect (Kahneman, 2003a; Kahneman, 2003b; Kahneman & Tversky, 2000). In a lab environment, the frame has already been assigned in the decision problem. But in the complex environment, the investigation of what the prevailing frame is and how the decision frame is formed would be a central issue in exploring the framing effect. In assessing the phenomena of the "passive acceptance of the decision frame" and the "prevalence of narrow frames", the characteristics of the stimuli (event or decision context) (Kahneman, 2003b) and the attributes of decision makers (Tversky & Kahneman, 1981) may serve as the basis for identifying and discriminating the

patterns among decision makers[8].

Based on behavioural decision theory, the occurrence of differentiated framing effects can be possible under the condition that decision makers have different "experienced utilities" based on perceived changes of the state (Kahneman & Tversky, 2000). Yet the role of cognitive ability in reducing the influence from the framing effect is questioned when there are no "usable cues" in the decision context. (Kahneman, 2003b: 7)**.** In this sense, behavioural decision scholars imply that decision makers' cognitive capacity is not necessarily relevant to the evaluation of judgment and decision under uncertainty[9]. On the other hand, organizational decision scholars have a different perspective on this assertion. The next section will discuss organizational decision theory of selective attention.

[8] Kahneman and Tversky recognize the fact that decision makers' characteristics may influence the heuristics judgment (Kahneman 2003), but discerning the patterns based on decision makers' cognitive ability is not the focus of the behaviour's decision studies.

[9] However, there is a slight distinction between Kahneman and Tversky in their later research: compared with Kahneman's focus on the "short-term experience effect" (Kahneman 2000), Tversky's emphasis on the role of belief could be associated with the decision makers' cognitive capacity in certain conditions.

2.2 Organizational decision perspectives

This section reviews the concepts of selective attention and attention- based view. Key aspects of organizational decision process are discussed.

Selective attention

In the concept of bounded rationality, Simon describes the role of selective attention in the process of channelizing the stimuli: “a stimulus, external or internal, directs attention to selected aspects of the situation to the exclusion of competing aspects that might turn choices in another direction”. The attention is limited by “the span and the areas of skills and habitual behaviours” (Simon, 1996a: 101). Therefore the focus of attention is selected by a particular value, knowledge, or behavioural pattern which can be a learned response from the exposure to previous information or activities (March & Simon, 1958; Simon, 1996a). Using this classic definition, bounded rationality can be explained within the limits of selective attention, which encompasses the individual and organizational aspects. The scarcity of attention suggests that decision makers may only attend to the salient and accessible aspects of their environments. Simon describes the role of environmental stimuli (external or internal) as “surprise”, which is the mechanism to focus attention on noticing opportunities or problems (Simon, 1996a: 123). In other words, the focus of attention is directed through selective perception towards the environment.

In respect to the underlying mechanism for selective attention, there are two views that arise from the tradition of organizational and management cognition studies. One view is that selective attention is driven by the mechanism of organizational

identification, in which shared expectations and goals are emphasized in shaping the attention focus of decision makers (Cyert & March, 1992; Dearborn & Simon, 1958; March & Simon, 1958). This perspective emphasises organizational influence in the judgement and decision process. The other view suggests that individual decision makers "enact" the environment, and that they notice and make sense of the environment through the mechanism of a "perceptual filter", which is influenced by both organizational and individual characteristics (Starbuck & Milliken, 1988; Weick, 1979). With more emphasis on decision makers' professional roles and experience, this perspective implies that while senior managers from different firms (in the same industry) may perceive the environmental stimuli differently, managers in the same organization may not necessarily agree on the influence of the environmental stimuli (Finkelstein, Hambrick, & Cannella Jr, 2009; Starbuck & Milliken, 1988).

Key concepts of selective attention in the organizational and individual aspects are summarized and compared with the behavioural decision perspectives in **Table 2.2.**

Table 2.2 Selective attention - the organizational and individual aspects

	Key concepts	Divergence with the behavioural decision perspectives	Linkage with the behavioural decision perspectives
Organisational aspect	Firms' economic position, social structure and top management team are the sources of variation	The common psychological mechanism (resulting in the similar pattern) is stressed in the behavioural decision perspective.	Selective attention as the critical factor influencing the differential of accessibility in the heuristic judgmental process
	The allocation of attention in the problem-solving process is demonstrated in firms' search activities	The problem-solving search is not the focus in the behavioural decision perspectives in which the judgmental process is emphasised	Both the concept of selective attention and framing concerns with the process of interpreting the decision problem
	The search sequence and alternatives are influenced by organisational goals, expectations and operating procedure	The possible phenomenon of "loosely coupled framing and choices" is not examined in the behavioural decision perspectives.	
Individual aspect	The role of expertise (particularly at the senior manager level) differentiates the attention and actions	The potential of the System 1 (intuition expertise), particularly for judgment under uncertainty is questioned by the behavioural decision perspectives	Extended the claim of experience effect from the behavioural decision scholars, some organisational scholars emphasise the limitation of experience on the role of expertise.

Attention-based view

Built on the concept of selective attention, the following scholar suggests linking the

"cognition and structure" aspects: the *attention based view* proposes a "socially structured pattern of attention" view in understanding firms' behaviour and strategic choices. It argues that the firms' behaviour can be explained by the issues on which they focus their attention. This view stresses its "open system perspective" that links multiple level of analysis. Thus in addition to individual cognition, the influence of the special situation of the decision context is highlighted in this *attention-based view,* in which three "premises" are proposed in the analytical framework: "focus of attention", "situated attention" and "structural distribution of attention". While emphasizing "individual cognition – attention processing", it argues that "firms' rules, resources and social relation *structure attention* in organizations…. and generate a set of decision premises and motivations for actions". Therefore, in analysing firms' decision behaviour, the application of this perspective suggests that sources of variation can be analyzed through the firms' attention channels which may depend on the firms' economic position, organizational structure and rules, as well as CEO and Top Management Teams' characteristics (Ocasio, 1997:188, 189,196). An empirical study adopting this "attention-based view" found that in the context of airline deregulation in the United States (Airline Deregulation Act of 1978), the change of managerial attention was observed, and the pattern of the attention shift was mediated by Top Management Teams' characteristics and the relevant incentive structure within the organization (Cho & Hambrick, 2006).

Organizational decision process

Organizational scholars propose that organizational decision structure and operating procedures may shape the organizational decision process (Cyert & March, 1992; Simon, 1996a). Specifically, organizational structural factors are said to influence

these rules, and may illustrate the differences among organizations. The implication of this perspective is two-fold in the concepts of frames and framing: firstly, it suggests that organizational decision process is influenced by organizational decision frame of shared goals and expectations. Secondly, the influence of the standard operating procedure or policies implies that the choices may not necessarily link with framing (the interpretation of the decision problem).

The role of contingency is stressed in the organizational decision process within the organization. Scholars suggest that the "small contingency" and "complex interaction" of organizational structural factors shape selective attention in the decision process (Ocasio, 1997: 191; 202). March proposes the "garbage can model", in which "temporal sorting" is emphasized in the organizational decision-making process (March, 1994: 199). He suggests that the choices and the influencing factors are linked by the timing of the decision context. According to March, "the linkage is formed partly because of the simultaneity" (March, 1994:205). Two implications from this perspective: the first is the effect of causal combination with respect to the influence of the organizational structural factors. Thus applying these organizational structural factors as the prediction base for the decision pattern may depend on the feature of the choice context and decision task. The second is that the concept of "temporal proximity" (March, 1994: 200) corresponds with the behavioral decision concept of narrow framing in choosing "local options" (March, 1994: 14), and the tendency of short-term focus in the adaptive decision process.

2.3 The two-system view

This section discusses the concept of the two-system cognitive process. From behavioural decision perspectives, the two-system view illustrates the operation of the psychological mechanism in the judgment and decision process. Here it is also relevant in exemplifying the different focus between behavioural and organizational decision perspectives.

System 1 and System 2

Two modes of cognitive process are distinguished here: System 1 is characterized by the automatic, effortless and associate process, which may correspond to intuition. System 2 is characterized by the controlled, effortful and deductive process, which may correspond to reasoning (Evans, 2003, 2008; Kahneman, 2003a; Kahneman, 2003b; Kahneman & Frederick, 2002; Sloman, 2002; Stanovich & West, 2002). System 1 and 2 can be viewed within the concept of "the operating system – software, not hardware" (Morewedge & Kahneman, 2010: 439). In addition to their speed and controllability, System 1 and System 2 can also be differentiated by their contents: while System 1 usually focuses on concrete and specific examples, System 2 can deal with abstract ideas (Kahneman & Frederick, 2002). In explaining the behavioural decision model using the two-system view, Kahneman suggests that as System 2 refers to explicit expression and monitoring, it can be involved in the judgment from both the impression generated by System 1 and the reasoning activated by System 2. However, "the difference in efforts" between System 1 and System 2 implies that the two systems "compete with resources" in the limited human cognitive capacity (Evans, 2003; Kahneman, 2003a). According to behavioural decision theory, System 2

is not always "actively and effectively" monitoring System 1; therefore decision biases occur, as people are satisfied with the "plausible judgments that come quickly to mind" (Kahneman, 2003b: 699).

In addition to their characteristics within the cognitive process, the roles of System 1 and System 2 may also depend on the conditions of the decision context, such as the available information, or the salience of the environmental cues (Kahneman, 2003b; Stanovich & West, 2002). Thus the rise of biases can be caused by the way that the System 1 automatic process passes the System 2 control process (Kahneman, 2003b), or simply because of the lack of information regarding the decision task (Kahneman & Frederick, 2002; Tversky & Kahneman, 1974). From the latter account, judgment and decisions under the uncertain context are indeed more susceptible to the heuristic judgment and framing effects predicted by behavioural decision theory.

Focusing on the operations of System 1 process, behavioural decision scholars assert that the role of decision makers' attributes in this automatic judgment process is minor. But other two-system scholars argue that the characteristics of the decision makers are still significant in discriminating the operating process between System 1 and System 2. (Stanovich & West, 2002). This brings us to the discussion of how the two-system view illustrates the differences between behavioural organizational decision perspectives.

Bounded rationality with different directions

Behavioural decision theory has its roots in the concept of "bounded rationality", which it shares with organization decision theory (Gilovich et al., 2002; Kahneman,

2003b). The evolutionary explanation that historical constraints influence the judgment and decision process is also embedded in behavioural decision theory. Similar to Simon's work, Tversky and Kahneman have been concerned with the decision process driven by the "satisficing principle" through the mechanism of memory retrieval (Gilovich et al., 2002; Kahneman, 2003b; March & Simon, 1958; Simon, 1996a).

However, the "bounded rationality" concept extended in the behavioural decision research program takes a different direction from the original concept developed by Simon. In behavioural decision theory, the decision "errors" are systematic, and are caused by the common psychological mechanism operating in the cognitive process. In the classic bounded rationality theory, Simon emphasizes that decision errors are caused by limited human cognitive capacity in decision-making (Simon, 1996a). In this sense, it appears that Simon does not entirely reject the notion from the rational decision model that decision errors can be unsystematic (Gilovich et al., 2002). Compared with Simon's problem-solving decisions emphasising the cognitive process, Tversky-Kahneman's decisions are more involved with the automatic judgment and perceptual process. Yet *cognitive* and *perceptual* may not be an appropriate way to discriminate Simon's (and behavioural decision scholars') emphasis on the decision process. In fact, even Tversky and Kahneman use the terms of perceptual and cognitive process "interchangeably" in their studies (Gilovich et al., 2002; Kahneman, 2003b).

The two-system view may illuminate the different perspectives between Simon's bounded rationality and Tversky-Kahneman's heuristic judgment. While both perspectives recognize human cognitive limitations, Simon appears to focus more on

the System 2 constraints in capacity: the lack of knowledge or limited computing power in processing the information are causes for potential decision errors (Simon, 1996a). On the other hand, Tversky and Kahneman focus on the constantly active functioning of System 1; the decision biases are results from the "lazy" or disrupted functioning of System 2 (Kahneman, 2003b; Kahneman, 2011). Therefore, as Simon focuses more attention on exploring ways to avoid System 2 errors in the problem-solving decision process, the original concept of bounded rationality may neglect the possibility that System 2 could still be overridden by System 1 – which is the proposition addressed by behavioural decision scholars. For example, the challenges for the problem-solving decision process are: firstly, despite an environmental change the decision makers may not be aware of the changing problem; secondly, even if they recognize the problem, there are issues regarding the judgment on the timing and the impact level.

Then the challenge for behavioural decision scholars is that they appear to assume that the effective functioning of System 2 would lead to superior decisions, and pay less attention to potential System 2 errors resulting from the deficiency of knowledge and computing power- which is emphasized in Simon's bounded rationality. Thus the challenge for behavioural decision perspective is that there is a danger of neglecting the factors influencing the System 2 capacity in the decision process.

With the two-system view, the divergence of focus in Simon and Tversky-Kahneman's decision models may lead to different diagnoses about the influencing factors in the decision process. For example, in the case of overconfidence, the behavioural decision scholars suggest the reason is because "people are more sensitive to the strength of the evidence than its weight" (Griffin & Tversky, 2002).

The underlying process can be explained by the representative and availability heuristics. On the other hand, the perspective of decision expertise (pioneered by Simon) (Chase & Simon, 1973; Ericsson, 2006a) may imply that the characteristics of the domain-specific expertise could induce cognitive traps or inflexibility (Dane, 2010)**.** Further, although behavioural decision scholars are aware of the potential influence of decision makers' selective attention in the System 1 judgmental process, the issue has not really been addressed in behavioural decision theory. Yet from the perspective of organizational scholars, the effect of selective attention is central in the organizational decision-making process (Cho & Hambrick, 2006; March & Simon, 1958; Ocasio, 1997; Simon, 1996a).

Chapter 3

Research Design

Introduction

This research encompasses enquiries from two aspects: one is the assessment of judgment and decision pattern; the other is the investigation of the decision makers and the choice context. The behavioural decision school focuses on the former inquiry and adopts the experimental approach. The advantage of this approach is that it delineates the patterns and conditions for the prediction base of the judgment and decision behaviours. But the challenge is that a laboratory environment may not reflect real-world decision problems. The organizational decision school emphasizes the latter inquiry and examines the influencing factors on multiple levels in the decision context[10] (Ocasio, 1997). The advantage of this approach is that it provides a comprehensive analysis of the decision process. Under this "open system" perspective (Ocasio, 1997: 188), everything matters and can be contingent on the situational factors. However, the question then arises that it may not necessarily illustrate the pattern for the prediction of the decision behaviour. This research design incorporates the ideas of the behavioural and organizational decision approaches: it employs the behavioural concept of eliciting the judgmental heuristics from detecting biases (Kahneman & Frederick, 2002) and draws on the organizational concept of examining the influencing factors across different levels.

Section 3.1 reviews various approaches including survey, content analysis,

[10] Here it refers to the organizational decision perspective of selective attention.

experiments, verbal protocol analysis and case study. Particularly, the limitations of experiments, verbal protocol and case study approach are examined. This section discusses that case study can be the most suitable approach for this research because it facilitates the investigation of supporting factors, causal rules and conditions for predictions. Then this section discusses that under the case study approach, this research incorporates some design elements of the experiments and verbal protocol analysis in this research design.

Section 3.2 discusses the three-level research design. The first level of research design focuses on examining the systematically similar patterns predicted by behavioural decision perspectives. The analysis focuses on examining heuristic judgement in the specific industry and institutional context. The second level examines the diversity predicted by the organizational decision perspectives. The comparative analysis focuses on examining firm-level selective attention. The third level investigates the relative influences of professional experience, organizational and industry practices on decision makers' selective attention.

Section 3.3 reviews the data collection and analysis approach of this research. Three categories of data collection sources include the industry, case firms and interviews. Validity is addressed through the selection of credible data and the triangulation of various sources. The data analysis follows the three levels of research design and uses the principle of comparative analysis to exemplify the theoretical concepts.

3.1 Approaches to decision studies

The complexity of decision studies presents different challenges for various research methods. Several approaches including survey, content analysis, verbal protocol analysis and case study have been employed in empirical management decision studies (**Table 3.1**).

Table 3.1 Approaches to the study of management decision –making

Approach	Research inquiry	Data Source	Study
Survey	How organizational characteristics contribute to the perceived uncertainty	22 decision groups	Duncan 1972
		212 managers	Milliken 1990
	How industry and organizational affiliation influence perception	307 senior managers	Sutcliffe 1998
Content analysis	How CEO attention influence response to change	71 firms	Kaplan 2008
	How TMT characteritics mediates firms' attention to change	30 firms	Cho& Hambrick 2006
Verbal protocol (think loud) problem analysis	The influence of role-based expertise on decisions	5 VP and 3 CFO	Melone 1994
	Differences in perceiving risk between bankers and entrepreneurs	4 entrepreneurs and 4 bankers	Sarasvathy et al.1998
	The influence of prior knowledge in opportunity recognition	9 entrepreneurs (executives)	Gregoire et al. 2009
Case study- single case	How internal selection environment mediate the strategic action	Intel	Burgelman 1994
	The relationship between cognition and capabilities	Polaroid	Tripsas & Gavett 2000
	Ho cognitive frames influence strategy making	A communication product manufacturing company	Kaplan 2008
Case study - multiple cas	Strategic decision process in high velocity industry	4 firms in microcomputer industry	Bourgeois & Eisenhardt 1988
	How regularity uncertainty influence investment decisions	5 firms in power plant industry	Hoffmann et al. 2009

Source: compiled by the author.

Survey

Surveys are one of the commonly used methods in examining management perception towards environmental uncertainty, particularly in early and 1990s organizational studies (Duncan, 1972; Milliken, 1990; Sutcliffe, 1998; Thomas et al., 1993). The advantage of a survey is that it can be a less expensive way to collect data targeting a large group of respondents. However, there are limitations of conducting survey to examine senior managers' perception. Firstly, it could be difficult for senior managers or executives to fill in the questionnaire given their busy schedule. The issue becomes a critical one if the characteristics of senior managers are central to the analysis and the researcher is not able to verify whether or not these senior managers are the ones who complete the survey questionnaire. Further, in the research context of examining firms' business decisions, the survey method cannot facilitate the need for verifying the answers with the respondents and explaining the questions if senior managers have any confidentiality concern.

Content analysis

Content analysis, particularly the approach of counting of critical words in letters to shareholders has emerged as another popular method of examining management cognition in the early 2000s (Cho & Hambrick, 2006; Eggers & Kaplan, 2008; Kaplan, 2008a; Kaplan, 2011). Content analysis generally refers to as a "systematic examination and interpretation of a particular body of material to identify patterns and meaning" (Berg, 2006:303). The major advantage of content analysis is that it can be used "non-reactively" in collecting and analyzing data. Moreover, it can be a cost-effect way for process study such as comparing the trends or "indicating the magnitude" in different periods of time. The major weakness of content analysis lies in the relevance of these "non-obtrusive" and recorded messages to the research

question (Berg, 2006:326-329). For example, one criticism of using the word counting is that it does not take into account the "literal" meaning used in the context. In this research, content analysis is used as a supporting analysis tool rather than a main research method. For example, in analysing Letter to Shareholders (LTS), this research applies the qualitative content analysis of "concept" rather than "word counting" in examining both physically present content and latent content.

The Experimental method

The experimental method is employed in most of the behavioural decision research program. From a general view, experiments "isolate or create conditions to investigate predictions" (Webster & Sell, 2007:194). There are two key elements in experiments. The first is that the characteristics of a situation must recur to enable the repeated study. The second is that the created and specified situations are served as the conditions to predict the outcome. The advantage of experimental method is its strength in "assessing theoretically derived predictions". Specifically, if the supporting evidence is derived from the subjects matching the specified conditions in a theory, it is others' problem to demonstrate that the theory cannot be held for some "subsets of the population" (Webster & Sell, 2007:192, 196-197). The experimental method is employed in most of the behavioural decision research program. It achieves the goal of identifying systematic pattern of judgemental heuristics.

However, there are limitations to using experiments. First, the situations created in experiments can be very different from those in real life. Therefore, it raises the question as to whether the lab findings can be "directly generalized" to the environment outside of the lab given the varied conditions. For example, as most of the findings from behavioural decision theory are established from the experimental

results, the main challenge for the behavioural decision research program lies in the question that people may act differently in natural settings[11]. Second, it has been suggested that experiments are not suited for answering questions with respect to exploring "orientations" or in need of "background interpretation" in specific context and time period (Webster & Sell, 2007:195).

Verbal protocol analysis

Verbal protocol analysis is an experimental method examining the "underlying thought processes that occur during problem solving". Specifically, in the "think-aloud" approach, subjects' immediate verbal expressions of their thinking processes are "elicited, recorded and encoded" for analysis. Verbal protocol analysis has been widely regarded as a valid approach for studying "expert thought" and complex thinking process (Ericsson, 2006b:224, 229). A number of management cognition studies have applied this method in examining senior managers' cognitive structure in the problem solving process (Gregoire et al., 2009; Melone, 1994; Sarasvathy, Simon, & Lave, 1998). There are several advantages in using verbal protocol analysis to examine decision-making as the problem-solving process. Firstly, compared with other verbal reports (such as interviews), the concurrent verbalization of the problem-solving process may avoid the "reactive effect of generating explanation", referring to the potential issue that participants may make other inferences or "after-the-fact reconstruction" in explaining the decision problem. Secondly, with standardized conditions and process measures targeted representative and domain specific tasks, verbal protocol analysis elicits the features of the cognitive structures and rules in a specific domain, not just the general problem–solving

[11] Scholars have criticised the lack of considering social influence in the choice context (Kogut, 2008), and the manipulated decision frame in the decision problem (Stanovich & West, 2002).

strategies (Ericsson, 2006b:230-231).

However, these "constrained conditions necessary" for yielding valid data in verbal protocol analysis are just the limitations of this approach. First, as it requires the "well-defined" and "representative task analysis, the question lies in whether the "specific tasks and activities" defined in verbal protocol analysis can really "capture the essence" of certain type of expertise under the "recreated and standardized conditions" (Ericsson, 2006b:231, 236). For example, verbal protocol analysis can be good in understanding and predicting the expert performance in the domain of memory, computation and chess but may not necessarily be a good indicator for medical tasks (Ericsson, 2006b; Lipshitz, Klein, & Carroll, 2006). Second, verbal protocol analysis aims at "revealing the sequences" and structure of thought processes; the implicit assumption is that expert performance of these representative tasks can be reproduced. But in real world people can be easily influenced by the decision context and employ different strategies in the decision process. This corresponds with the same limitation faced with the experimental method[12].

The case study approach

The case study approach have been employed in a number of organizational decision studies (Bourgeois III & Eisenhardt, 1988; Burgelman, 1994; Hoffmann, Trautmann, & Hamprecht, 2009; Kaplan, 2008b; Tripsas & Gavett, 2000). The major goal of case study is deep understanding of a case. With "thick descriptions" (Mabry, 2008:214, 219)of analytic details, case study is strong in examining the complexity of

[12] One of the major differences between the behavioural decision experiments and verbal protocol experiment is that the latter aims at identifying the reasoning pattern from the controlled System 2, taking the opposite path to the experimental approach of the behavioural decision school in eliciting the heuristics from the automatic System 1.

interrelated factors. Also, while case study "retains more noises" in real life, the investigation permits the exploration of the "unexpected" or "unusual" cases and factors (Hodkinson & Heather, 2001; Platt, 2007).

Limitations of case study

The major limitation of case study generally points to the issue of *generalizability*, referring to "the capacity of a case" to reach "generalization for causal propositions" beyond the specific context of a case (Mabry, 2008:222; Platt, 2007:108). In quantitative study, the "case-to-population generalization" emphasises the representativeness of a population through random sampling. However, random selection may still be susceptible to skewing findings because of sampling bias (Mabry, 2008:223). Further, the assumption of sharing similar causal principles in randomized control trials raises the practical question as to whether these empirical findings can really be applied in other settings (Nightingale, 2013).

Therefore, scholars have argued that the generalization mode from case study is "theoretical" not "empirical" from the statistical perspective. For example, the concept of "analytic generalization" emphasises the "theory in question is embedded in a broader web of theories ….. to link specific study findings to the theory of interests". Also, because the selection of cases is based on their "informativeness", the choices of examining exemplar, deviant or extreme cases reflect different features of the study and may help modify or strengthen the theory (Mabry, 2008:223; Platt, 2007:108, 113-114). Further, case study may aim at comparing rival theories and applying the findings in other settings (Hodkinson & Heather, 2001). For the latter account, case study can be a way to facilitate the investigation of supporting factors,

causal rules and conditions for predictions. It will then help to make the valid claim for the effectiveness of practical policy or management advice (Nightingale, 2013).

Another limitation of case study is the issue of *validity*, referring to the "accuracy of data" and "warrantedness of data-based interpretation". Observation, interviews and document analysis are the three main qualitative data collection methods employed in case study research (Mabry, 2008:221,218). Particularly, observations and interviews tend to be easily criticized for the "subjectivity" issue. For example, compared with experiment methods, interviews usually lack the rigor and control of environment and measurement. Data collection and interpretation is highly dependent on the researcher's own judgement and experience. In addition, there are other potential limitations associated with using interviews method in case study. First, the accuracy and credibility of the interview data may rely on the assumption that interviewees "understand the question intended by the researcher" [13] (Alvesson, 2011:114,143).Second, the retrospective issue arises when using interviews for decision studies: there is doubt as to whether interviewees may rationalize their behaviour in explaining the decision process[14] With respect to the senior manager interviewees, another potential worry is that whether they answer some questions with the purpose of impression management.

To address the validity issue of case study, *triangulation* is the common principle. Scholars have suggested "triangulation by data sources", referring to collecting data

[13] In this sense, survey method relies on this assumption, too. Verbal protocol analysis also has the similar assumption that the participants have the ability to express their spontaneous thought in the problem-solving process.

[14] Verbal protocol analysis is strong in addressing the retrospective issue. While survey method suffers the same issue, interview method is stronger than survey because the interviewers have the chance to remind interviewees about the time line and verify their responses in the interview process.

from different stakeholders and sources. “Methodological triangulation”, referring to verifying data with different methodologies: for example, examining whether interviews data confirms with document analysis or observation. “Theoretical triangulation” refers to examining different implications suggested by various theories. Finally, “triangulation by observer” may help to expand the angle of interpretation and address the potential subjectivity issue resulting from the single researcher. With respect to interviews, in addition to employing the principle of triangulation in interviewing different stakeholders and examining related “supportive studies” (Mabry, 2008:222), it is suggested that some “thoughtful intervention” such as intentionally increasing certain level of control and assessment can be employed to enhance the validity of interview practice and process (Alvesson, 2011:143).

Case study approach in this research

This research selects the case study approach because it is most suitable in investigating the research questions “*what is the role of framing in the decision-making process for new capability investments, and what factors may influence such process?*” The case study approach addresses the complexity of interrelated factors in the decision–making process and facilitates the analysis of specified conditions for predictions in the decision context.

Although with the strengths of controlled measures and assessing theoretically derived predictions, the limitations of experiments are the reasons why the pure experimental method is not suitable for this research. As discussed earlier, the first limitation is that while the situations created in experiments can be very different from those in the real world; this research aims at understanding of behaviours outside

of the controlled lab environment. The second is that while experiments are not suited for answering questions with respect to interpreting specific background, this research concerns exploring firms' orientations in natural settings..

There are two reasons why verbal protocol may not be suitable for the investigation of this research: firstly, similar to the limitations of using experimental methods, although the way verbal protocol analysis in "eliciting, recording and encoding" verbal reports in well defined task analysis can be valid for investigating the expert thought in specific domain. But these controlled environments and conditions are opposite to this research question investigation in which the behaviours in natural settings and the influence of the decision context are the central concerns. Secondly, whereas the central interest of verbal protocol analysis draws on the understanding of "cognitive constructs and rules" (Ericsson, 2006b:237), such topic of diagnosing thinking process and expert performance is not the central interest of this research.

While case study is most suitable in examining firms' behaviour and the interactions of factors in the decision context, some design elements of experimental approach and verbal protocol analysis are incorporated in this research design**.** For example, the concept of eliciting heuristics in behavioural experiments is employed in this research: it uses structured questions to elicit interviewees' comments on specific incidents and then their remarks are compared with industry data to yield the pattern of heuristics used in the judgment process. Further, although not using the verbal protocol approach, this research purposefully selects the subjects fitting the scope of conditions (e.g. the professional experience in certain corporate functional role) and uses the

concept of eliciting patterns, cues and action plans[15] in the judgement and decision process. In particular, besides using semi-structured and structured interviews, this research also employs the scenario evaluation tool to capture the pattern of opportunity recognition.

This research uses both the single- case and multiple case study approach. The single-case presentation aims at understanding the specific decision context and process. The multiple case comparison facilitates the exploration of diversity and causal combination among cases (Ragin, 1997; Ragin, 1994b, 2007). With respect to enhancing the validity of case study and interview approach, this research employs the principle of triangulation. Firstly, this case study research is not purely relied on interview data but also uses document review, industry analysis and content analysis of Letter to Shareholders. Secondly, this research interviews senior managers with different functional roles and relevant third-party stakeholders including government official, research community, venture capitalists and different industry participants in the value chain. Meanwhile, prior to the formal interviews, this research employs expert review to enhance the credibility of the structured interview questions and scenario design. Finally, the retrospective issue is lessened because the forward-looking responses are emphasised in the scenario evaluation approach.

[15] In this sense, the concept is similar to Natural Decision Making (NDM) approach in which pattern analysis and decision making under natural settings are emphasised. However, it is different from NDM in terms of the research goal – NDM concerns the expert performance.

3.2 Research design principle and case selection

This section discusses the three-level research design and the rationale of case selection.

Research design 1

Three levels of research design are employed in the research **(Table 3.2)**. At the first level, the research design aims at examining the phenomenon of framing effect suggested by the theoretical concepts from the behavioural decision theory. On the one hand, this level of the research design focuses on the decision makers' perception toward the decision issues and follows the concept of detecting decision makers' potential biases. On the other hand, it also emphasises the investigation of the choice context; specifically, the salience of the environmental cues and the sources of uncertainties. The use of the qualitative approach in this research design is to exemplify the similarities across cases. With the goal of seeking commonalities to identify general patterns, (Ragin, 1994b), the case selection strategy is to justify the representativeness of the selected cases for the validity of the plausible explanations.

Table 3.2 Research Design

	Research Design 1	Research Design 2	Research Design 3
Examined theoretical concepts	1)Heuristic judgment and framing effect - Behavioural decision perspective	1)Selective attention (Organisation aspects - resources/capabilities and management structure)	1)Selective attention (individual expertise) - management cognition perspective
		2)Framing effect - Behavioural decision perspective	2)Framing effect - Behavioural decision perspective
			3)Deliberate mechanism - organisational and behavioural decision perspectives
Goals	1) Examine commonality	1)Explore diversity and causal complexity	1)Categorise relationship patterns
	2)Identify general patterns	2)Identify sources of variation	2)Identify sources of similarities and variation
Approach	Qualitative case study	Comparative case study	Quasi- experimental concept
Case selection strategy	Comparable cases - Minimize the variance of contextual factors	Comparative analysis - sharpen the comparison by increase the homogeneity of cases	The criteria of professional background and representing the firm's decisions
	Justify the representativeness (the salience of the investigated conditions)	Selecting on the independent variable (organisational causal factors)	
Selected cases	Five Taiwanese PV firms	Three c-Si firms (out of the five Taiwanese PV firms)	Eight senior managers (Four technical decision makers, Four business decision makers)

Source: The author.

Following the experimental concept of theoretical sampling in the comparative approach, the cases are purposefully chosen and comparable in a defined category in which the variances of the contextual factors are minimized, yet the interested factors are saliently demonstrated (Ragin 1994, 2009). Firstly, to control the influencing factors from the different institutional and industry environments (DiMaggio, 1997; Kaplan & Tripsas, 2008), the research setting is located in a single industry in the same country. In view of the uncertainties, the Solar Photovoltaic (PV) industry is selected as the appropriate industry setting. Taiwan is selected because the Taiwanese PV industry has experienced impressive growth for the past few years. These two conditions lead us to a specific investigation period of the years 2006-2011, to exemplify the influence from environmental change. Secondly, as the firms' position in the industry value/supply chain is expected to influence their investment strategies (Adner & Kapoor, 2010; Teece, 1986), I focus on firms in a similar position in the industry value chain. PV cell firms are selected because they represent the vast

majority of the PV firms in the Taiwanese PV industry (PIDA, 2011; WealthPress, 2009).

Next, as the research concerns firms' capability investments, the condition of similar networking and access to external technological resources is controlled. The participation of the government R&D innovation programs serves as the criterion. Two programs from the Ministry of Economic Affairs (MOEA) are used, because they are benchmark government programs for R&D innovation projects in terms of both the scale and the strict review process by a group of experts from academia and the research community.

There are a total of eight PV cell firms, in four categories of PV technologies, which have been awarded MOEA programs over the past five years (2006-2011). However, not all of the eight firms could be studied, due to constraints upon resources and access. The five case firms were selected[16] according to the below criteria **(Table 3.3)**. Firstly, three out of the four Crystalline Silicon (c-Si) firms were chosen because they had been awarded the most recent projects. The one excluded firm's last award was in 2006. Secondly, the one selected Amorphous Silicon/Macro Crystalline Silicon Thin Film (a-Si/μc-Si TF) firm was awarded with more government innovative R&D programs in recent years than the other a-Si/μc-Si TF firm. Thirdly, the only Copper-Indium- Gallium-Diselenide Thin Film (CIGS TF) firm was selected. Lastly, the Dye Sensitized Solar Cell (DSSC) firm was omitted because the firm withdrew the DSSC business line in 2011.

[16] Case firms are given as pseudonyms

Table 3.3 Case firm profile

Case firm profile					
	Solar one	***Greenchild***	***FabPV***	***Amorphous***	***Newsun***
PV Technology (main)	c-Si	c-Si	c-Si	a-Si TF	CIGS TF
Firm establishment date	1981 (Entry SolarPV cell in 2000)	2004	2005	2007	2007
Firm size (Employees)	2157	588	960	50	91
Market Type	Over-the-counter listed in 2003	listed in 2012	listed in 2009	Private	Private

Source: Company annual reports, MOEA projects and TSE (Taiwan Security Exchange) filing. Compiled by the author.

Research design 2

The second level of the research design aims at examining the phenomenon of selective attention suggested by the theoretical concepts from organization decision theory. While this research design addresses the sources of variation at the organization level, it also emphasizes explaining which organizational factor or causal combination discriminates the patterns across firms. With the goal of exploring diversity in mind, the second level of research design has a stronger flavour of the comparative case approach than the first because it is "more concerned with causal complexity" in the organization.

To sharpen the comparison at the organization level, another condition is added to increase the homogeneity of the comparable cases (Ragin, 1997). With the condition of c-Si PV technology, the cases are narrowed down to the three c-Si firms. The reason for choosing c-Si technology is that this technology is relatively mature. Thus

these c-Si firms are similarly associated with a certain scale and public trading type. In fact, these two factors obviously differentiate the three c-Si firms from the other two thin film firms (besides the technology). The exclusion of the two smaller firms not only facilitates the collection of public data but is also justified for the purpose of comparative analysis at the organization level.

Research design 3

Continuing the investigation of the phenomenon of selective attention as the source of variation, the third level of the research design examines whether individual decision makers' attributes influence the framing effect. Specifically, the research design focuses on categorizing the relative influence of individuals' professional backgrounds, and organizational decision contexts. With the goal of examining individual decision makers' attributes and identifying sources of similarities and variation, the similar concept of the quasi-experimental approach is adopted in the research design, but with a modified implementation approach. The decision problems are not designed from hypothetical cases, but are drawn from the real business environment. Rather than following the verbal protocol approach in coding the specific term or semantic analysis to recognize cognitive patterns, the research design focuses on the description of the decision issue, and the analysis of the interaction with the decision context.

With the concept of the quasi-experimental approach in management cognition studies, each interviewee is purposely selected to meet the criterion of a professional background. Two functional groups – technology (R&D) decision makers and business (finance) decision makers – are categorized in the research. Initially, the

research targets ten senior managers (one for each functional group) from the five case firms. Finally, eight senior managers are available for interview. This size is considered reasonable as it matches the average group size of eight to nine in previous management cognition studies employing the quasi-experimental approach (Gregoire et al., 2009; Melone, 1994; Sarasvathy et al., 1998). Among the eight senior managers, four are in the technology function group while the other four are in the finance function group **(Table 3.4)**. Most of the senior managers (except the deputy Chief Finance Officer) are the heads of their departments. In fact, it may be more appropriate to refer them as executives of the firms. Generally, their positions reflect their expertise in the function group. For example, of the four senior R&D managers who joined their firms since inception, three of them have PhDs and research experience in the field of PV technologies.

Table 3.4 Senior managers' profile

	Interviewee (senior managers)	Education background	Experiences
Technology Decision Maker			
	Solar one CTO	PhD in Material engineering	join the firm in 1999 (since PV business inception)
	Amorphous R&D Head	BS in Physics	join the firm in 2007 (since inception)
	Newsun CSO	PhD in Optics engineering	join the firm in 2007 (since inception)
	Greenchild R&D Head	PhD in Electric engineering	join the firm in 2005 (since inception)
Business Decision Maker			
	Solar one- Deputy CFO	MBA	join the firm in 2011; previously investment banker
	Amorphous- GM	PhD in Mechanical engineering	join the firm in 2007(since inception)
	Newsun Board of Director	MBA	join the firm 's board in 2007 (since inception)
	FabPV - CFO	MBA	join the firm since 2010; previously CFO in an electronics group

Source : Company annual reports, interviews and compiled by the author.

3.3 Data collection and analysis

This section reviews the data collection and analysis approach of this research. Archival documents and interviews are the main sources of data. The emphasis is on the triangulation of the different data sources as well as among firm and third-party interviewees. Data analysis follows the structural approach of the three-level design.

Data sources

The PV industry

The first stage of data collection begins with the PV industry. The analysis of the PV industry is not simply conducted for the purpose of background information; it also serves as the basis for examining uncertainty in the choice context. Further, in order to investigate decision issues in real business environments, an understanding of the industry is essential for the design of interview questions.

In addition to the primary goal of amassing comprehensive information, the collection of industry data ensures the principle of validity. Firstly, the data sources encompass perspectives from different industry stakeholders, including governments, industry associations (NGOs), research and academia communities, investment bankers and industry analysts. Secondly, I pay specific attention to the credibility of the data providers. For example, I reviewed the industry reports published by the major government agencies, leading PV industry interest groups and top financial institutions. Thirdly, the data sources comprise a variety of media formats, including professional white papers, books and market reports, as well as business news. Then

comes the observation: to gain a practical perspective on trends within the industry, I attended two of the largest international Solar PV conferences and exhibitions[17], and had conversations with a number of industry participants during the trade shows.

Case firms

From the solid base of PV industry knowledge and networking, the second stage of research was to review the background information of the five case firms. Firstly I reviewed the annual reports and extensively researched all the relevant business news regarding the case firms. Specifically, I examined details of the three c-Si firms' annual reports, including the shareholder and organizational structures, financial performance and investment projects, as well as key announcements in the board meetings. An additional stage of research was to collate the relevant interviews of (or news regarding) the case firms' CEOs and collect any related remarks from the third-party interviewees. Secondly, the details of the five case firms' MOEA government projects were examined, with specific attention paid to the technologies[18] and the collaborating partners. Moreover, as the two thin film firms are private, the information from MOEA projects provided some company data that is not publicly available. For the three c-Si firms, the MOEA information provided another source for cross-checking the data from the firms' annual reports.

Interviews

Aided by the MOEA officials' support as well as by the researcher's personal contacts

[17] EU PVSEC in September 2010 and InterSolar in June 2011.
[18] For the non-confidentiality aspects of the technologies; with permission from the MOEA official.

(friends and networking from tradeshows), the interview arrangement began in parallel with data collection from the case firms. Prior to formal interviews with senior managers of the case firms, I conducted expert reviews (pilot interviews) with three industry professionals to validate the interview questions[19]. To arrange the official interviews, I sent emails to target interviewees, in which the purpose of the interview and the profile of the researcher were briefly introduced. Then the confirmations were followed by subsequent emails or calls. Finally, I managed to interview eight key decision makers in five case firms, and six industry third-party stakeholders.

As discussed earlier, the representativeness of the eight senior managers is exemplified by their position in their firms; it is also provided by the assumption that senior managers' perception may reflect the firms' decision process (Cyert & March, 1992; Finkelstein et al., 2009; Starbuck, Barnett, & Baumard, 2008; Starbuck & Milliken, 1988). The representativeness of the six third-party interviewees is also well justified in that the selection encompasses the government, the research community, the venture capital community, and industry players in the value chain. Also, these interviewees are qualified in terms of their professional positions as well as their experience within the industry (**Table 3.5)**. These official interviews were conducted during the period of November 2011 to March 2012. The interview time ranged from one to two hours (for senior managers from the case firms), to two to three hours (for the industry professionals).

Table 3.5 Interviewees' profiles

[19] The expert interviewees also agreed to participate in the formal interview (from the perspective of third-party stakeholders).

		Interview profiles					
		Firm					
Function/direct connection with the firm		*Solar one*	*Greenchild*	*FabPV*	*Amorphous*	*Newsun*	
Technology Decision Maker							4
	Chief Technology Officer (CTO)	◆					
	R&D Head		◆		◆		
	Chief Strategy Officer (CSO) *1					◆	
Executive Board (Business Decision Maker)							4
	GM				◆		
	CFO			◆			
	Board of Director *2					◆	
	Deputy CFO *3	◆					
Govt. Project partner (Research institute)							2
	PV Division Director		◆	◆	◆	◆	
	Project manager	◆					
Govt. official - MOEA project leader		◆	◆	◆	◆	◆	1
Pilot interview informants (also 3rd party informants)							3
	Project manager of Solar PV system						
	Former solar PV firm (polysilicon) R&D Head						
	VC						
Total							14
◆: experience (working or interacting)with the firm							
*1: Former R&D Head							
*2:VC (major shareholder)							
*3: Attend Board meeting (for investment projects)							
*4:Former project manager in Government Research Institute							

Source: the author.

Interview question design

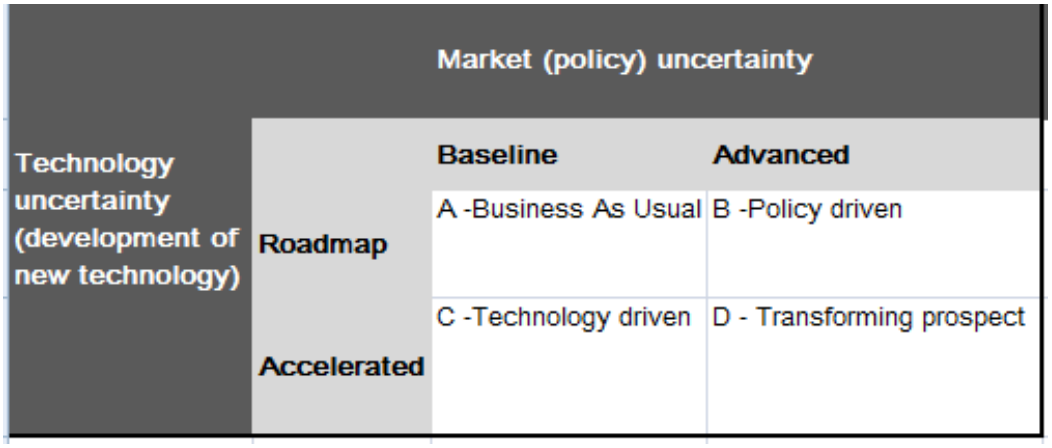
Two perspectives are adopted in designing the interview questions. On the one hand, the retrospective interview questions focus on the firms' activities relevant to capability investments, including the MOEA projects, search activities in R&D and the firm's decision issues. Senior managers' responses were triangulated with the interviews with third-party industry stakeholders and archival documents including annual reports, industry sources and government records. On the other hand, the investigation of "decision frames" and "framing" is examined through interviewees' perceived environmental uncertainty, and future trends. These related questions are

constructed around the scenario analysis. The concept of the case scenario has been used in management cognition studies, mostly in the form of the survey or the verbal protocol approach (Gregoire et al., 2009; Melone, 1994; Thomas et al., 1993). In contrast to the hypothetical case scenario employed in these studies, the scenario here is built on the basis of solar PV industry analysis.

The design of the scenario is based on the idea that through addressing the interaction effect of the influencing environmental forces, the industry dynamic can be visualized to reflect the business context (Day, Schoemaker, & Gunther, 2000). Two major forces which are of particular interest to the industry, and critical in shaping its future development are identified: policy uncertainty and technology uncertainty. Firstly, the impact of policy uncertainty on the PV market can be categorized through two scenarios – baseline and advanced – according to the level of introduction and the enforcement of the government support measures (EPIA, 2010). Secondly, the two scenarios of technology uncertainty – the roadmap scenario and the accelerated scenario – are categorized by the development pace of the emerging PV technologies relative to the prediction from the current technology roadmap (IEA, 2010; SEMI, 2011, 2012). Finally, combining the interaction effect of the policy and technology uncertainty, four scenarios are identified: *business as usual*; *policy driven*; *technology driven;* and the *transforming prospect* **(Figure 3.1**). Interviewees were asked to rank the relative predictability and possibility of scenarios, and then evaluate their influence on the firm's timing and direction regarding new capability investments. Specifically, interviewees would select a most probable scenario, and indicate the location of the chosen scenario. Meanwhile, interviewees were also asked to describe the relative influence of the policy and the strength of the technology. In this way, the researcher would be able to identify and discriminate each interviewee's evaluation

within the selection of a particular scenario.

Figure 3.1 Scenario analysis



		Market (policy) uncertainty	
		Baseline	Advanced
Technology uncertainty (development of new technology)	Roadmap	A -Business As Usual	B -Policy driven
	Accelerated	C -Technology driven	D - Transforming prospect

Source: the author.

The interview process and organizing data

In the last confirmation email of the interview appointment (usually two or three days prior to the interview), I emailed the interviewees the question list[20]. Two issues needed to be considered: one was that the question list could not be too long, because it might intimidate busy senior managers who had other things to do. The other was that the list needed to cover the topics under discussion: because of their positions as the firms' executives, they would be sensitive to unexpected questions in the interviews. Therefore, the question list I sent prior to the interview included the key questions, but presented them in a concise manner[21]. The question list was in both Chinese and English. Then, at the interview meeting, I prepared the complete interview question list with instructions and detailed descriptions. I found that this

[20] Some secretaries or assistants of the senior managers requested the question list even earlier (i.e. as soon as their bosses confirmed the meeting).
[21] I found that every interviewee did read the question list before the interview.

helped to clarify the terminologies and questions during the interview process.

I did not record the interviews, because making recordings was frowned upon due to the sensitive position of the senior R&D managers involved[22]. Instead, I took notes during the interviews. These notes were recorded quickly, and in brief form. Therefore as soon as the interview was completed, I reviewed these notes immediately at the firm's reception lounge (if it was allowed), or on the train home. Then when I got back to my desk, I wrote down detailed elaborations on these notes, following the 24-hour rule (Bourgeois III & Eisenhardt, 1988). I also had the chance to re-examine the interview questions during phone conversations with some of the interviewees.

I did not use the coding method for specific terms. The focus is not on the frequency of the usage of certain terminologies, but on descriptions in the responses, particularly in terms of the open questions (e.g. the critical issues influencing capability investments). In some of the structurally-designed questions (e.g. the scenario, or market signals), or questions with prompts (e.g. investment evaluation criteria or search activities), I was able to compare the interviewees' responses both on the indicated ranking and in the corresponding descriptions. For some of the questions, I triangulated with the answers from the third-party interviewees: for example, in the question on the firms' search activities and the decision practices. For some questions, such as the opinion on future prospects, the interviewee's individual comments already adequately met the purpose of the questions.

[22] I have provided the confidentiality assurance in the interview invitation. But some senior mangers still raised some concerns prior to the interviews and suggested that I interview PR managers instead. PR managers would, however, be the wrong interview target, so I tried to ease their concerns. Non-recording was one the courtesies.

The categorization of the interview data serves as the preliminary analysis framework. To organize the interview data, I started by grouping the similarities and differences among cases. Firstly, the comparison was organized using three interview sections – the scenario and market signals, MOEA projects, and R&D strategy. Then in organizing the scripts of the interview responses, I briefly listed each interviewee's points using tabular display forms. These tables include the comments from third-party interviewees and notes from archival sources. I found such visual representation helped in analysing and discriminating patterns among case firms and individual managers (Eisenhardt, 1989).

Analytical approach

The three-level analysis framework is constructed based on the three research design principles described earlier in Section 3.2.

Research analysis level 1

The first level of analysis emphasizes the commonality among the five case firms. The analytical strategy of "selecting the dependent variable" is adopted to examine the causal condition shared by the five cases with similar outcomes (Ragin, 2007; Rihoux & Ragin, 2009). Here the causal condition is the framing effect suggested by the behavioural decision perspective. The dependent variable is the firms' investment patterns in the investigated period (2006-2011). The focus on existing capability investment is verified as the general pattern shared among these Taiwanese PV firms.

Following the investigation of the pattern of environmental uncertainty in the decision

context, the analysis focuses on comparing the theoretical concepts from behavioural decision theory with rival explanations from the rational decision models: for example, how does the investigated phenomenon deviate from the prediction of the rational decision perspectives? The analysis approach of eliciting heuristics is adopted. The researcher then examines the pattern of when heuristic thinking would arise, and which heuristics would be invoked. Specifically, the analysis focuses on the framing of environmental uncertainty, investment project evaluation and resource constraints. Interviewees' responses are compared with evidence from industry data. Then, using the concept of data triangulation across cases (Ragin, 1994b), the similarities of these cases serve to exemplify the phenomenon of systematic patterns suggested by the behavioural decision perspective. The empirical findings of this level of analysis are discussed in **Chapter 4**.

Research analysis level 2

The second level of analysis focuses on diversity among the three c-Si firms, following the logic of comparing the differences among cases under the selected conditions. The analytical strategy of "selecting the independent variable" is adopted in order to investigate the diverse causal pattern among the three firms (Rihoux & Ragin, 2009: xix). There are two dependent variables based on the two investigation problems: one is defined as the three firms' capability investment patterns throughout the firm's history. The other is the three firms' selective attention pattern. As verified by desk research, there is variation of patterns among the three firms. In the analysis of the first investigation problem, three firms' selective attention patterns are compared to examine the relevance to their capability investment pattern. Then, in the analysis of the second investigation problem, the independent variables are the

investigated causal conditions derived from the organizational decision perspective *(the attention based view*). Specifically, three organizational factors influencing the selective attention are examined and compared within the three firms: firm resources, firm ownership, and firm CEO's experience. Finally, the comparative method of configuration is introduced by constructing a simple truth table summarising the causal combination of the comparative analysis of the three firms (Ragin, 1994b, 2007). The empirical findings of this level of analysis are discussed in **Chapter 5.**

Research analysis level 3

The third level of analysis focuses on examining the conditions influencing selective attention at the decision maker level. While the comparison logic of senior managers' professional experience is similar to the verbal protocol approach employed in management cognition studies, the difference lies in the analysis here also encompasses the investigation of the relative influences from the organizational and industry context.

Data sources are mainly based on interviews with the five case firms' senior managers. Firstly, selective attention (represented by opportunity recognition) is examined from three aspects, including the perception towards the long-term market trend (from market scenario analysis), short-term market signals, and technology development. These senior managers' responses are then cross-analyzed with their firm and functional group affiliation. Secondly, as competition is indicated as one of the most salient signals influencing the decision to make capability investment, the perceived competition and the comparison with industry data is investigated.

Thirdly, to incorporate the influence from the industry context, these senior managers' responses on the firms' search activities are examined. Data sources focus on interviews with the R&D senior managers and these firms' MOEA projects. The design of the investigation focuses on the firm's search activities relevant to new technology development, referencing the innovation management literature (Freeman & Soete, 1997a; Tidd & Bessant, 2009). In addition to their remarks about the firms' search activities; senior mangers' weightings for these activities are examined, and cross-analysed with the firms' data. The empirical findings of this level of analysis are discussed in **Chapter 6.**

Chapter 4

Uncertainties and Framing

Introduction

Chapter 4 examines the process of framing external environmental uncertainty to answer the research question: *what is the role of framing in the decision-making process for new capability investment?*

The analysis of Section 4.1 indicates the potential judgment issue of framing environmental uncertainty for capability investments. Section 4.2 starts with examining the general concept of perceived environmental uncertainty and proposes the behavioural decision concept of diminishing sensitivity to uncertainty. Given that perceived uncertainty may not sufficiently explain firms' investment decision pattern, the analysis then leads Section 4.2 to investigate what are the additional influences explaining the focus on exploitation. Section 4.2 applies the behavioural decision concept of narrow framing effect to analyze two empirical investigations: the first is the propensity of optimistic market forecasts for growth opportunities derived from exploitation investments; the second it the tendency of isolating the uncertainties and future opportunities in assessing investment projects.

Section 4.3 identifies additional influences which help to explain the specific findings about Taiwanese PV firm. Section 4.3 starts with an assessment of the influence of demand-pull and technology-push policies in Taiwan. The analysis suggests that both policy measures are not evidently influential on Taiwanese PV firms' capability

investments. Then Section 4.3 discusses an empirical investigation showing the heuristics judgment process of *attribute substitution* in framing the resources issue. Finally, advancing the application of the narrow framing effect in the concept of prevailing frame, Section 4.3 argues that the industry and institutional experience effect reinforces narrow framing and thus help to explain Taiwanese PV firms' exploitation focus.

4.1 PV industry dynamics

Section 4.1 starts with examining the influence of policy uncertainty in the PV industry. Then it explains how the characteristics of PV technologies and key industry concepts of LCOE and system cost structure inform us about technological uncertainty and the exploitation/exploration issue in the context of PV industry. Finally, this section discusses the PV industry transition and Taiwanese PV firms' investment pattern during the period of 2006- 2011.

Feed –in-Tariff, (FiT), policy uncertainty and market demand

The PV industry has shown significant growth for the past decade. Government incentive policy, particularly FiT (Feed-in-Tariff) has been considered as the main force in driving the demand of the solar PV industry in the past few years (EPIA, 2011; Fulton, 2010; IEA, 2009, 2011; O'Rourke, Kim, & Polavarapu, 2010).[23] Under the FiT scheme, utility operators can purchase the power generated by customers' solar PV systems on a guaranteed rate in a 15-25 year period. A degression rate is included in the FiT program to balance the anticipated cost reduction of the solar PV system. The design and implementation of the FiT has driven the growth of the solar PV market, because it provides guaranteed return on investment (ROI) for the solar PV projects. Thus the deployment capital for PV has been driven by the market which provides the most attractive return (Fulton, 2010).

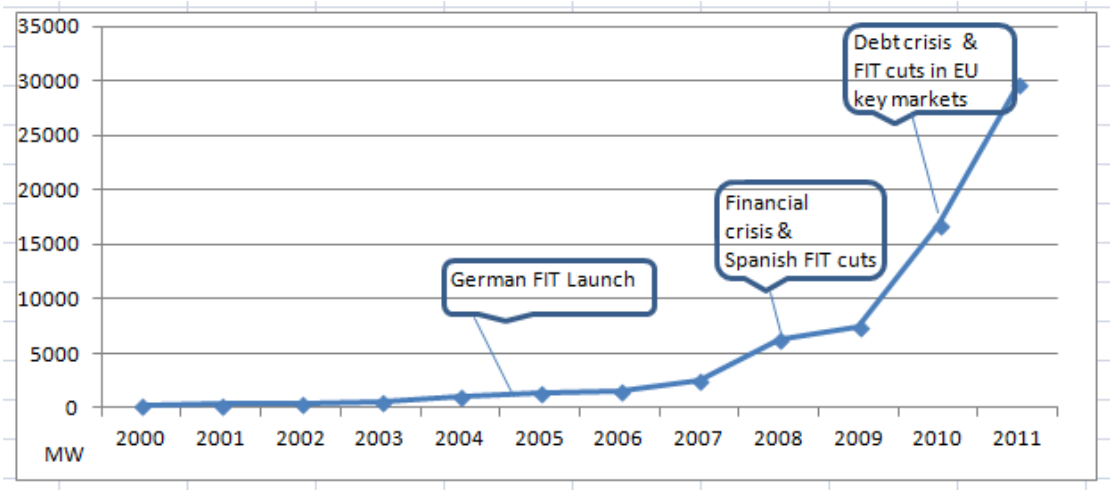
With the root in the Renewable Energy Sources Act in 2000, the adoption of FiT was

[23] Compared with other key government support measures for renewable energy sources such as tax credits and direct capital subsidies**,** FIT is generally regarded as the most favourable scheme for the solar PV (IEA 2009).

officially launched in Germany in July 2004 (Fulton, 2010; Fulton & Capalino, 2012; Hoppmann, Huenteler, & Giord, 2014). Then this government incentive program was widely adopted in EU countries. With the implementation of FiT, EU (particularly Germany) has become the major solar PV market since the emergence of the PV industry. Such market concentration on specific regions and countries seems to suggest the industry's vulnerability to policy uncertainty, which is inevitably correlated with both economic and political situations.

Policy uncertainty in the PV industry was coincided with the timing of global financial and EU debt crisis in the past few years. Yet the data showed that the global PV market demand was not necessarily influenced by the uncertainty of government incentive policies. In fact, PV market reported record growth in 2011 despite EU debt crises and continued government incentive cuts **(Fig. 4.1)**.

Fig. 4.1 Global PV Annual Installations 2000-2011



Source: industry sources(ECJRC, 2011; EPIA, 2010); data compiled by the author.

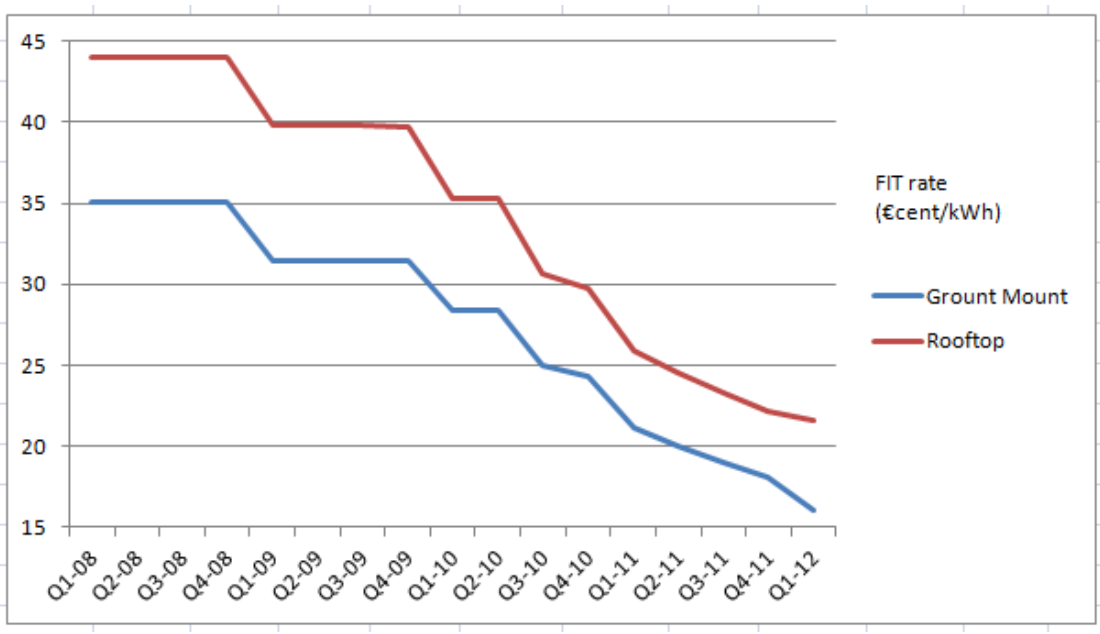
Policy uncertainty in Spain and Germany

Here policy uncertainty in the PV industry is illustrated by the two representative cases of Spain and Germany. In 2008, Spain took the lead of the global solar market following announcement of the generous FiT scheme in June 2007. The annual PV installation in Spain surged from 544MW in 2007 to 2.7GW in 2008, which accounted for around 50% of the global PV installation in 2008. Then the Spanish market collapsed soon in 2009 (the annual PV installation turned to zero in 2009) after sizable reduction in the incentive scheme (ECJRC, 2010; Rio & Mir-Artigues, 2014). Both policy design and policy uncertainty are considered to cause the dramatic up and down of the Spanish PV market. Because the design of degression schedule was not incorporated in the Spanish FiT in 2007, PV project investors and developers saw excess guaranteed profits. For example, the ROI of some projects were estimated to reach 10-15%, which is much higher than the targeted 5-9%. Then, the one-year transition period for adopting the new reduction program was too long, which inevitably induced the *rush installation* in a short period of time. Moreover, economic uncertainty also triggered the collapse of the Spanish PV market, particularly on the aspects of government tariff deficit and credit crunch for PV project financing starting in 2008.

In Germany, the government announced first FiT cuts in 2009: in addition to the upward adjustments of the degression rates (8 to10%), a dynamic degression schedule was introduced to substitute the static 5% degression rate prior to 2009. Other changes in FiT include the additional one-time remuneration reduction and the caps based on previous installation. Then, further FiT cuts were announced in 2010 and 2011 with accelerated degression rates of 9 to 13% and 12 to 15% respectively. Generally, FiT rates were reduced by 23 to 25% from 2009 to 2010, and 25 to 26% from 2010 to

2011(Hoppmann et al., 2014; Kim & Polavarapu, 2011) **(Fig. 4.2).**

Fig. 4.2 German FiT Rates 2008-2011



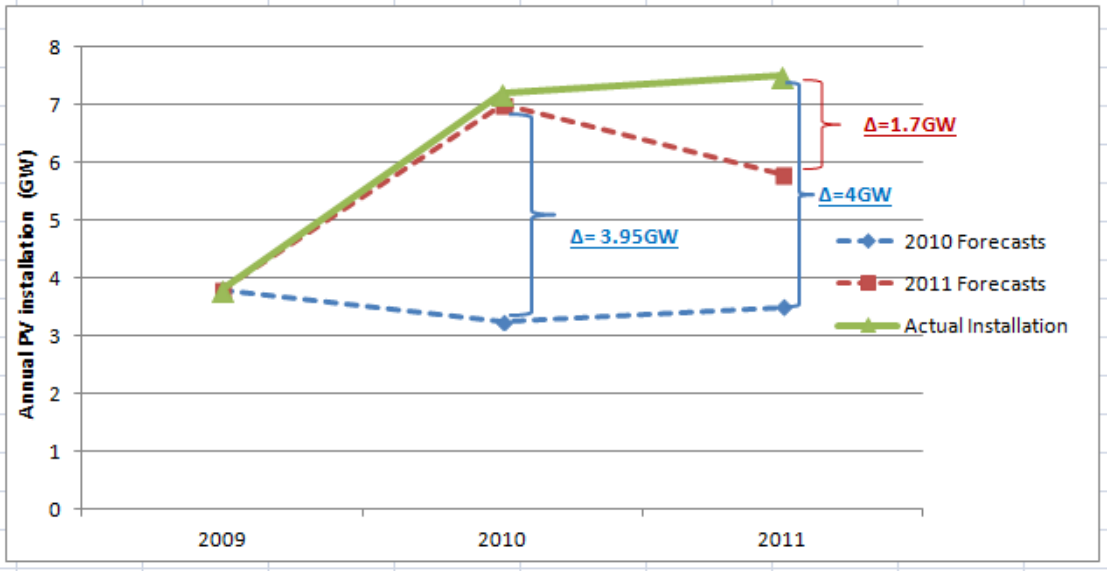
Source: Deutsche Bank 2011 Estimates(Kim & Polavarapu, 2011), data compiled by the author.

The forecasted and actual impact of German FiT changes

As the design of German FiT mechanism aimed at regulating market demand and incorporating PV technological progress (Fulton, 2010; Hoppmann et al., 2014), it was expected that the PV market demand would be reduced after the announcement of FiT cuts. For example, analysts estimated that following FiT cuts in 2010, the annual PV installation in Germany could be managed to around 3 GW in 2010. But the actual PV installation turned out to be 7.2 GW in 2010. Then in early 2011, analysts forecasted that following further FiT cuts, the annual PV installation would be reduced to around 5.8 GW in 2011. The actual PV installation in Germany was 7.6GW in 2011(ECJRC, 2011, 2013; Kim & Polavarapu, 2011; O'Rourke et al., 2010;

Shah, J., & Min, 2014) **(Fig. 4.3)**.

Fig. 4.3 Forecasted vs. Actual PV installation in Germany 2009-2011.



Source: (ECJRC, 2011; Kim & Polavarapu, 2011; O'Rourke et al., 2010; Shah et al., 2014), data compiled by the author.

Beyond incentive policy mechanism

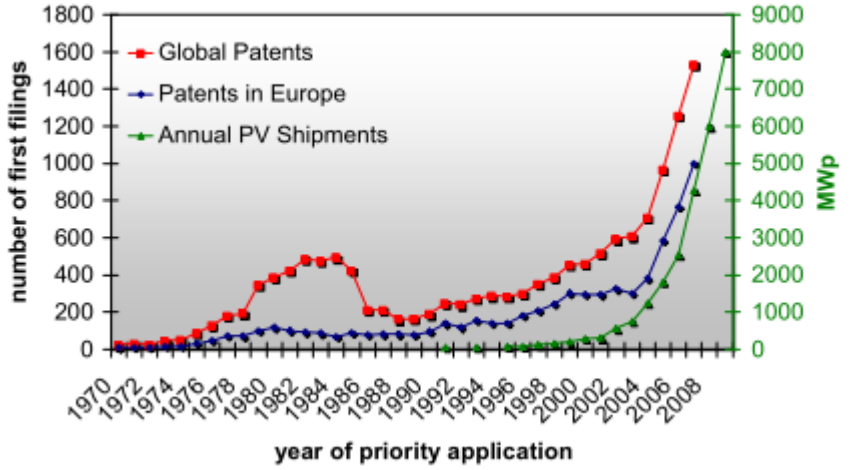
In explaining the discrepancy between the forecasted and actual PV market demand, industry analysts later emphasized the *short-term effect* of *rush installation* in accelerating the overall demand (Shah et al., 2014). Similar to the case of Spain, PV project developers and system integrators speeded up the installation in expectation of further incentive cuts and policy uncertainty. The demand acceleration was also caused by the faster PV module cost reduction than the predicted FiT degression rates (Bazilian et al., 2012; Fulton & Capalino, 2012; Hoppmann et al., 2014). Although the German FiT scheme has already incorporated the adjustment design following PV industry experience curve(Hoppmann et al., 2014), the pace of PV industry dynamic has speeded up since 2009. In particular, one important indicator is that PV module

ASP (Average Selling Price) has been falling much faster than expected. For example, as of 2012, the average PV module price has dropped more than 45% since 2010(Bazilian et al., 2012; Kim & Polavarapu, 2011). While PV cell/module manufacturers suffered from shrinking margins, the substantial decrease in PV module price has indeed stimulated the level of PV installation and deployment.

PV technologies – characteristics and technological uncertainty

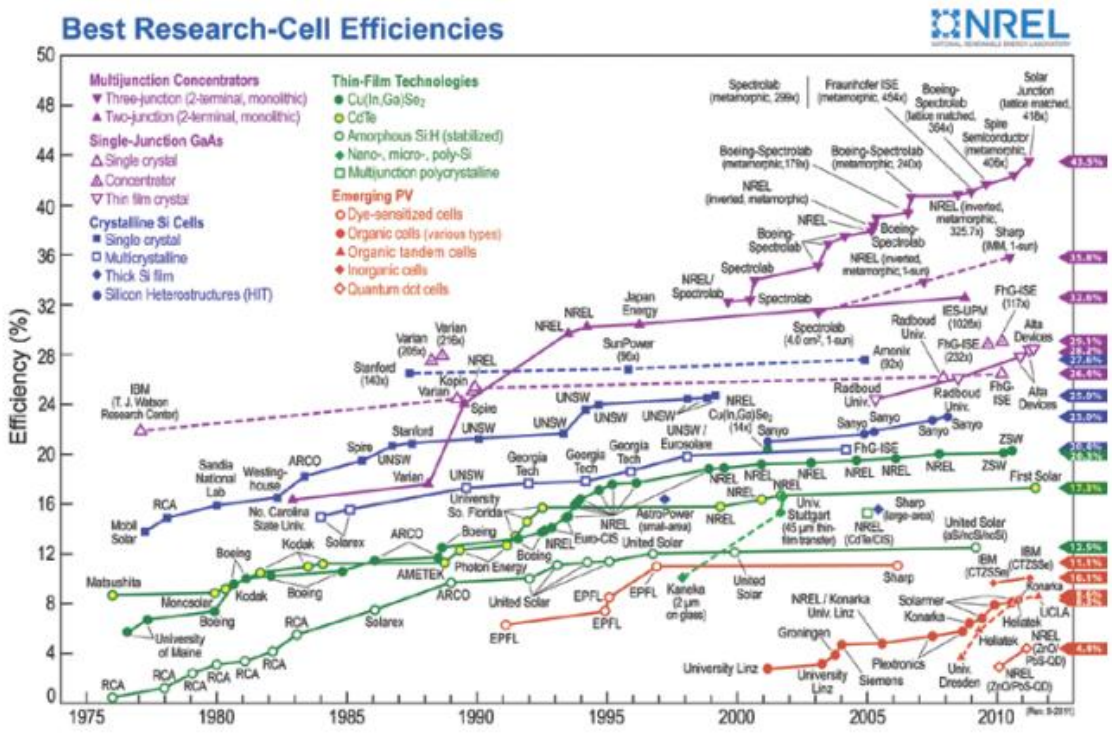
The development of PV technologies dated back to the 1950s: the Bell Lab researchers developed the first c-Si PV module based on silicon semiconductor technology. The oil crises of the 1970s then spurred PV technology development, particularly in US government research. The development of PV technology continued in the 1980s and 1990s, with efforts primarily funded from government research and universities(Bradford, 2006; Breyer et al., 2010). Since the introduction of FiT in 2004, the growing trend of patent application has been in line with the growth of PV shipment **(Fig. 4.4)**. If using patent counts as the measure, it appears to justify the claim that FiT is influential in inducing technological innovation(Hoppmann et al., 2014; Johnstone, Haščič, & Popp, 2009). However, judging from the development history of PV cell efficiency rate (the key indicator of PV technology performance), there has been no major technological breakthrough since the early 2000s (Selya & Robert, 2010) **(Fig. 4.5)**. This evidence is consistent with the finding from an empirical study of the wind power industry, in which the influence of government incentive policy in stimulating non-incremental technical change is questioned (Nemet, 2009).

Fig. 4.4 Annual PV applications (first filing) and shipment 1970-2009



Source: Figure adapted from EPO, Boneschanscher et al., 25th European Solar Energy and Exhibition 2010

Fig. 4.5 Best PV Research Cell Efficiencies 1975-2010



Source: Figure adapted from National Renewable Energy Lab Report (Selya & Robert, 2010).

PV: the manufacturing centric technology

Further, it highlights the characteristics of PV technologies – the development of research lab based cell is one thing, but how to achieve mass production with lower cost is another. In fact, as the lab results are based on small production quantities under ideal conditions, the efficiencies for mass-produced PV cells are lower than those produced in the lab, and the efficiency of the PV module is lower than the efficiency of the PV cell (Selya & Robert, 2010).

The manufacturing issue is central to the development of various PV technologies which are categorized by the differences in *materials and manufacturing technologies* of the PV cell: c-Si cells represents 85 to 90% of the global PV market share, thin-film based cells account for around 10-15% of the market[24]. A number of emerging PV technologies, including concentrator PV (CPV) and dye sensitized solar cell (DSSC, a branch of organic PV cell) currently only account for less than 1% of the market(EPIA, 2011; IEA, 2010).

There are two implications for the exploitation/exploration discussion in this research context. The first is that given the manufacturing-centric characteristic, development of a particular PV technology involves more than the simple purchase of a turnkey solution or equipment; it requires long-term investment in the manufacturing process. The second is that the investment of a different PV technology (other than the firm's current technology platform) would be an important decision to build new capabilities.

Technological uncertainty interlinked with commercial uncertainty

[24] There is a variety of thin-film technologies, but the majority of the global market share is from a single firm – First Solar, using Cadmium Telluride (CdTe) thin film technology.

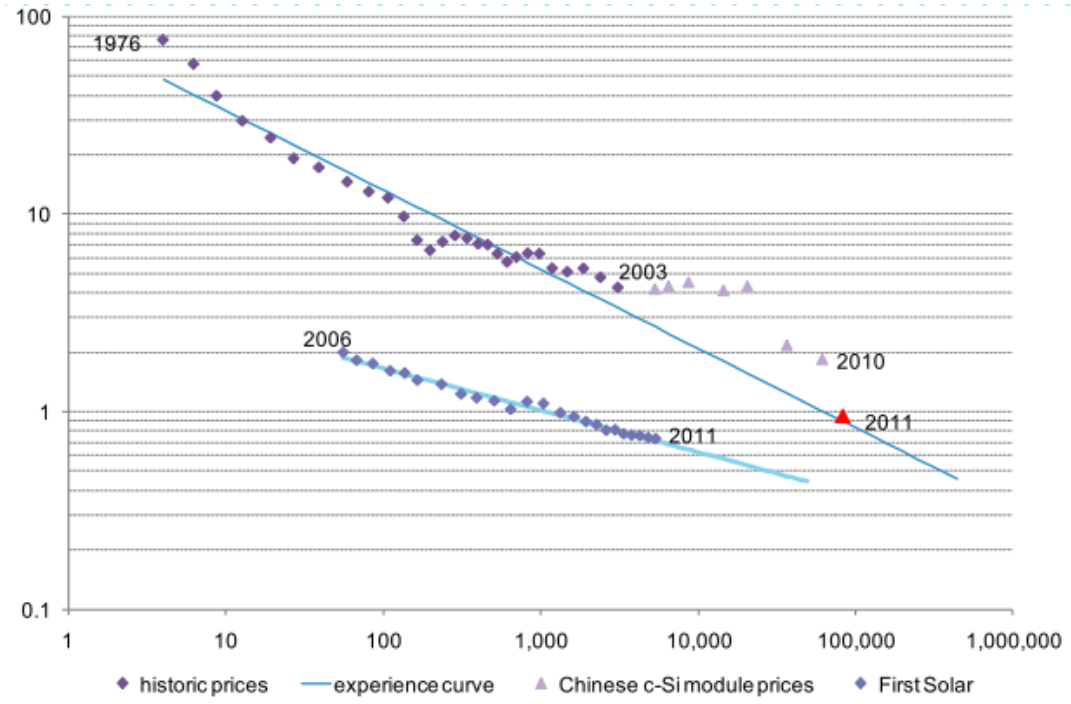
The long development history and the manufacturing-centric characteristic seem to suggest that technological progress in the PV industry is subject to some level of predictability. As indicated by the cell efficiency development in the past few decades (**Fig.4.5**), the uncertainty of "fundamental research and invention" may not necessarily be applied to PV technologies. In this research, *technological uncertainty* is defined as the development of emerging technologies relative to the prediction of current technology roadmap. Here technological uncertainty is distinguished from *technical uncertainty* which refers to the uncertainty of technical problems that could be reduced by investments in technical development or production improvement (Freeman & Soete, 1997b: 243-244). The definition of technical uncertainty is generally applied in the real options model, suggesting that such uncertainty is mostly on the project level and thus can be reduced by firms' investments (Dixit & Pindyck, 1994). As for *technological uncertainty,* it is related to industry-level dynamic and may not be reduced by firms' investments (Oriani & Sobrero, 2008; Tushman & Anderson, 1986). Therefore, with the definition of exogenous industry force, here the notion of technological uncertainty emphasizes the embedded element of commercial uncertainty in the PV industry.

The Impact of polysilicon price

For example, the development of an industry-shared c-Si technology roadmap more or less indicates the industry participants' collaboration in reducing the technology uncertainty (SEMI, 2011, 2012). The reduction of technology uncertainty of c-Si cells is also evidenced by the experience curve: the historical PV module price experience curve indicated that PV module price decreased around 15-24% when the PV shipments were doubled (**Fig**. **4.6**). It is generally suggested that manufacturing scale

definitely helped; and the advanced manufacturing process – particularly the improvement of efficiency – is undoubtedly the cost-down driver (Wawer, 2010). However, from a closer look at the PV cost structure, polysilicon is the key component in the price reduction, as it makes up around 20% of the total module costs. Thus in fact the sharp decrease in the cost of polysilicon since 2008[25] apparently contributed a much more significant portion of the PV module price reduction than the factors of increasing manufacturing scale and efficiency improvement(Bazilian et al., 2012; Nemet, 2006; O'Rourke et al., 2010).

Fig. 4.6 PV module experience curve 1976-2011



** First Solar is the largest CdTe Thin film maker.*

Source: Figure adapted from Bloomberg New Energy Finance report (Bazilian et al., 2012).

The fluctuation of polysilicon price has also influenced the development of other PV technologies. Despite with a slower pace in commercialization than c-Si cells, the

[25] Polysilicon cost was around $82/kg in 2008 dropped to less than $45/kg in the first quarter of 2011.

development of alternative PV technologies such as thin film and CPV can also be dated decades ago (**Fig 4.5**). In fact, the share of PV patent families of CPV and a-Si thin film has actually peaked earlier before 2000(Breyer et al., 2010). The commercial emergence of thin film PV was firstly encouraged by the rising silicon cost of the c-Si cells around 2005. Then in 2009, the scaling of the c-Si technology, coupled with the significant price reduction of polysilicon has dampened the investment for the development of alternative PV technologies which have already been struggling with high cost and manufacturing issues. Therefore, despite the potential in various applications and markets, the uncertainty level of these emerging PV technologies has been raised with the downward price trend of polysilicon price and the c-Si PV modules.

LCOE (Levelized cost of electricity)

The statement that technological uncertainty in PV industry is interlinked with commercial uncertainty can also be illustrated by the concept of LCOE (Levelized Cost of Electricity), the measure for comparing the generation cost of different energy sources. In the LCOE model, the sum of total costs is divided by total output (kWh). Main cost input items include PV system and installation cost, operation and maintenance (O&M) as well as financing cost (sensitive to interest rates) of the PV system. The output mainly refers to electricity generation -annual harvest which is not only associated with the yield rate (related to PV cell efficiency) of the PV system, but is also a function of local sun irradiation (Kim & Polavarapu, 2011). Another key concept of LCOE is that the cost is amortized over the life-time of the PV system (Selya & Robert, 2010).

With the concept of LCOE, there are two aspects for understanding the technological

uncertainty in PV industry. One aspect is that although c-Si cell/modules have a relatively complex supply chain in the upstream manufacturing process[26] and with limited potential in efficiency advancement, c-Si cell/modules have the advantage of proven long life- time and product reliability – which is crucial to LCOE as one of the key factors for technology adoption. From this perspective, the perceived technology uncertainty for c-Si cells is indeed lower than other alternative technologies – particularly from the viewpoint of downstream system integrators and end customers.

The other aspect is that the output calculation in LCOE illustrates that the economic feasibility of a PV system is sensitive to the cost of financing, locations and applications (Bloomberg, 2011a, b; O'Rourke et al., 2010). In other words, the value generation of the PV system depends on different market segments. Thus alternative and emerging PV technologies (other than c-Si technology) can have the unique advantages for opportunities in various market segments and applications. For example, a-Si/u-Si thin film is suitable for Building Integrated PV (BIPV) or customized solutions. CIGS thin film has the greatest potential in achieving comparative efficiency with the c-Si cells with much lower costs. CPV has the highest efficiency rate and particularly suitable for areas with high sun irradiation where the technology can demonstrate its advantages. As for DSSC, the low efficiency-rate cells have the potential to help in integrating end-consumer applications with their flexible texture and low cost. From the perspective of currently dominant c-Si firm, the investment in alternative PV technologies justifies the rationale to explore market potential in the PV industry.

The LCOE concept in explaining technological uncertainty hints the

[26] Please refer to Appendix 1: c-Si cells manufacturing supply chain.

exploitation/exploration issue particularly from the perspective of c-Si PV firms. Exploitation, the investment in current c-Si platform would involve the commercial uncertainty derived from the complex value chain and competition from numerous industry players**.** As there are proven applications and markets based on current platform, the judgment for the investment decision would heavily rest on the assumption of market demand forecasts**.** As for exploration, the investment in alternative and emerging PV technologies, the apparent issue lies in the variable stability of mass production. Further, there is commercial uncertainty associated with the cost-down pressure from c-Si cells and the prospect for developing niche market applications(IEA, 2010). The exploratory investment for emerging PV technologies relies on the expectation for future industry change and market development. However, in view of the uncertainties, it may not necessarily be easy to find justifications for exploration investment if based on measures in comparison with investments for exploitation. The investment decision of exploration would rest on the judgment of investment timing and the wiliness to take the chance with an attitude of experimentation(March, 2008).

Industry transition

The dominance of c-Si cells and the changing competition landscape (**Table 4.1**) illustrate the importance of scale and cost reduction in the PV industry over the past decade. Before 2005, the leading PV technology firms – including some Japanese and Europe-based companies – accounted for the worldwide top ten solar PV manufacturers; among them were several large electronic and oil companies. Since 2005, with the foundation of semiconductor manufacturing technologies and aggressive expansion, Chinese and Taiwanese solar PV firms have been starting to

take the lead. As of 2011, there were eight Chinese and Taiwanese c-Si firms among the top ten solar PV cell manufacturers[27].

Table 4.1 Worldwide top ten PV firms 2001, 2003, 2005-2011

	2001	2003	2005	2008	2009	2010	2011
1	Sharp (Japan)	Sharp (Japan)	Sharp (Japan)	Q-cells (Germany	First solar (US)	Suntech (China)	First solar (US)
2	BP (UK)	Shell (Netherland)	Q-cells (Germany	Suntech (China)	Suntech (China)	JA Solar (China)	JA Solar (China)
3	Kyocera (Japan)	Kyocera (Japan)	Kyocera (Japan)	First solar (US)	Sharp (Japan)	First solar (US)	Suntech (China)
4	Shell (Netherland)	BP (UK)	Sanyo (Japan)	Sharp (Japan)	Q-cells (Germany	Q-cells (Germany)	Yingli (China)
5	Schott (Germany)	Schott (Germany)	Mitsubishi (Japan	Kyocera (Japan)	Yingli (China)	Motech (Taiwan)	Trina (China)
6	Sanyo (Japan)	Mitsubishi (Japan)	Schott (Germany)	Yingli (China)	JA Solar (China)	Gintech (Taiwan)	Motech (Taiwan)
7	Isofon (Spain)	Isofon (Spain)	BP (UK)	JA Solar (China)	Kyocera (Japan)	Kyocera (Japan)	Gintech (Taiwan)
8	Mitsubishi (Japan)	Sanyo (Japan)	Suntech (China)	Motech (Taiwan)	Trina (China)	Sharp (Japan)	NSP (Taiwan)
9		Q-cells (Germany)	Motech (Taiwan)	Sunpower (US)	Sunpower (US)	Trina (China)	Canadian solar(China)
10		Photowatt (France)	Shell (Netherland)	Sanyo (Japan)	Gintech (Taiwan)	Sunpower (US)	Sunpower (US)
10				Solarworld (US)		NSP (Taiwan)	

Source: industry data compiled by the author.

The concept of the appropriability regime and complementary assets suggested in the PFI (Profit from Innovation) framework (Teece, 1986) may explain the rise of these Chinese and Taiwanese c-Si PV cell firms over the past few years. Although there are several leading c-Si patents being developed by some US and Japanese firms, these patents have not been proved to be cost competitive on approaching their expiry dates[28]. Further, not all PV technologies are patentable, especially those involved in manufacturing knowhow such as propriety process or material composition (Breyer et al., 2010). Therefore, while patent may not necessarily be an effective mechanism for appropriating profit, the complementary asset of cost-effective production can be critical in capturing profit during the industry growth period.

[27] First Solar is the only thin film (CdTe) maker among the top ten PV firms.
[28] For example, IBC (Interdigitated Back Contact) from Sunpower (US) and HIT (Heterojuction with Intrinsic Thin layer) from Sanyo (Japan).

Changing value proposition

Yet the value proposition applied for the past few years may not incorporate the recent changes in the PV industry. In fact, the rapid expansion of these Chinese and Taiwanese PV firms has planted the seed for the transition. Historically PV modules and BOS (Balance of System)[29] accounted for around 60% and 40% of the total PV system cost respectively (Bazilian et al., 2012; O'Rourke et al., 2010). Since the recent module price decline[30], BOS now accounts for around 50% of the PV system costs and represent the major source of cost reduction. The rising value of BOS is further demonstrated in the increasing need to integrate current intermittent and peak-loaded PV energy into the electricity network. Downstream players now have the potential to capture higher profit in the PV industry. (Bazilian et al., 2012; Bony, Doig, Hart, Maurer, & Newman, 2010),

Therefore, while the c-Si firms have been striving for technological advancement in cost reduction efforts such as efficiency improvement, the potential impact on the total PV system can be relatively limited - judging from both the PV system cost structure and the c-Si technology roadmap (SEMI, 2011, 2012). Moreover, given the prospect of continued oversupply and unutilized capacity, further price competition and margin squeezing is to be expected in the near future.

During the early growth period, scale and manufacturing excellence have been the sources of value capturing in the PV industry. Now with the expansion of

[29] Cost break-down for BOS include electrical system (particularly electrical installation and inverter), structural system (particularly racking and structural installation) as well as the business processes Bony et al, 2010).

[30] The trend of declining PV module price has started since 2008; in 2011, the retail price was actually lower than that of the manufacturing cost.

production scale and the commoditized manufacturing, the value proposition has shifted from upstream manufacturers to downstream players who own the customers. For Taiwanese PV cell firms, this transition represents challenges to access end customers and new markets. From the perspective of changing value proposition, the implication for *exploitation/exploration* issue in this research context is that while improving exiting capabilities of cost reduction through optimizing supply chain management and manufacturing process are still crucial to survive in the near-term, developing new capabilities in downstream business matters for the Taiwanese PV cell firms to capture the opportunities from industry transition.

Taiwanese PV cell firms' investment pattern

The five case firms' investment patterns are examined. Here new capability investments include the investment in alternative PV technologies (other than the firms' domain technology) and downstream system business. The vertical integration of c-Si PV modules (assembly) or the improvement of c-Si PV cell yield rates are not included as new capability development, because the majority of the efforts are based on exploiting the existing capabilities in c-Si cell technology.

Similar investment pattern focusing on exploitation

Based on the data from *MOEA projects* and the firms' *investment histories*, firstly, it shows that the majority of the MOEA projects were targeted at current technologies, not exploratory technologies[31]. Although *Greenchild*'s CIGS and *Amorphous*' CIGS

[31] *Solar one's* MOEA project leader claimed that "next generation cell structure is the firm's exploratory technology". However, the project is based on c-Si technology (the firm's current domain technology) and new cell structure is not new in the industry (EPIA. 2011. Solar Generation 6: EPIA.).

projects were the two exceptional cases, the former was not mentioned in the firm's annual report and the latter was later withdrawn **(Table 4.2).**

Table 4.2 MOEA projects

		MOEA projects	Current technology	Exploratory technology	2008	2009	2010	2011	2012	2013	2014	2015
Firm	***Solar one***											
		A1-Polysilicon wafer manufacturing	•			▲						
		A2-High efficiency cell (emitter)	•					▲				
		A3-Next generation cell structure	•					▲				
	Greenchild											
		D1-Polysilicon wafer manufacturing	•*		▲							
		D2-CIGS pre-study		•			▲					
		D3- CIGS development		•				▲				
	FabPV											
		E1- High efficiency cell (material)	•		▲							
	Amorphous											
		B1-a-Si/uc-Si and BIPV application	•			▲						
		B2- CIGS pre-study		•**		▲	**					
	Newsun											
		C1- CIGS manufacturing	•					▲				
Year					2008	2009	2010	2011	2012	2013	2014	2015
	*: *Greenchild* didn't continue the investment after MOEA project finished											
	**: *Amorphous* withdrew the MOEA project (one year earlier than planned)											

Source: MOEA projects and interviews; compiled by the author.

Secondly, as the three c-Si firms' senior managers stated that MOEA projects were not the firms' only new technology or capability investments, the three c-Si firms' investment histories from 2006-2011 are further investigated[32]. The data shows that the three c-Si firms were particularly similar in terms of the timing and investment for capacity expansion and vertical integration. Certain patterns were observed according to the investment time lines.

Also, the project output is still aimed towards efficiency improvement. *Newsun*'s CIGS project aims at resolving some measurement issues in the firm's CIGS production process.

[32] The two thin film firms' *(Amorphous* and *Newsun*) senior managers described that MOEA projects represented the firms' new technology investments. After examining the related business news from 2007-2011, there is no evidence relating to the two private firms' new capability investments since their inception in 2007.

From 2006-2008: the three firms were all engaged with production expansion, including new production lines or sites in Taiwan and China, which also reflects their rapid sales growth.

From 2008-2009: there are signs of a shared interest in polysilicon wafer-related projects[33]. The three firms' MOEA projects during 2008-2009 were all related to polysilicon technology[34]; these actions were then reasonably followed by the sharp price increase of polysilicon, which was caused by the temporary shortage of polysilicon in 2007-2008 (Bazilian et al., 2012; O'Rourke, Kim, & Polavarapu, 2009).

From 2009-2011: While these firms similarly experienced fluctuations of sharp sales decline and growth in 2009, this is very much a period marked by continued capacity expansion and the development of module operations (vertical integration). *Solar one* acquired module businesses in the US and Japan; *FabPV* set up a module company (Taiwan); and *Greenchild* launched new production sites and increased the proportion made up of its module business line. The investment in module manufacturing reflects these firms' intention to shift away from specialized cell manufacture towards a more vertical integration of cell and module businesses. This is in part triggered by the strong competition – based on low cost and large scale – from the big, vertically integrated Chinese c-Si solar PV firms.

Thirdly, regarding the investment of downstream capabilities, the three firms have had only limited investment in related activities compared to their aggressive product

[33] *Solar one* seemed to be a little ahead on the related investment with its acquisition of a polysilicon firm in 2006.

[34] Although not specifically targeted at polysilicon technology, the aim of *FavPV*'s MOEA project was mainly material (polysilicon) cost reduction.

improvement and capacity expansion plans over the past few years. As the first Taiwanese solar PV firm, *Solar one* actually started the business line in PV equipment and system integration in 2002, but this line has been relatively small and focused on the domestic market[35]. *Greenchild* had started some initial investment plans in overseas EPC business (US and India) through the firm's subsidiary in 2011, but the firm has not confirmed any continued investment in the near future. According to the firm's records and the interview data *FabPV* has had no investment in PV systems over the past few years. Regarding the two thin film firms, *Amorphous* had no further development on the BIPV application except the MOEA project, while *Newsun*'s senior managers stressed that the firm has only focused on achieving the mass production of CIGS thin film since the firm's inception.

Overall, the data shows that a similar investment pattern during the period of 2006-2011 is observed among the five Taiwanese PV cell firms: while these firms were able to catch the industry trend, they were not simultaneously actively investing in developing new capabilities. The next section will examine the reasons why the investment in exploiting current capabilities appears to be the main focus for the five case firms.

Summary

Two findings from the investigation of the influence of policy and technology uncertainty on firms: First, although FiT policy aims at regulating demand and supply on the basis of PV experience curve, the expectation of further incentive cuts induces a chain of responses in stimulating short-term supply and demand (i.e. rush

[35] *Solar one* did not officially announce new inverter products for overseas markets until 2012.

installation).

Second, the reasoning that incentive cuts favour low-cost manufacturers therefore influence their exploitation focus is based on the interaction between policy and technological uncertainty in the PV industry: As a manufacturing –centric technology, the exploitation investment strategy appears to be preferred by the c-S- cell/module manufacturers in view of capturing short-term profit induced by policy uncertainty and the seemly predicable technology roadmap. However, the influence of technological uncertainty can be underestimated – both on the aspects of commercial uncertainty associated with exploitation (particularly on PV cell/module) and the potential of emerging technologies. Here it points out a judgment issue of investment timing: it may not be easy to find justifications for exploration investment if based on measures in comparison with investments for exploitation.

The finding of Taiwanese PV firms' investment pattern during the period of 2006-2011 is consistent with the exploitation focus. Specifically, Taiwanese PV firms' investment strategy appears to be in line with the prediction from the perspective of complementary assets in the PFI framework. However, industry transition and changing value proposition hint the shrinking margin from PV cell/module manufacturing and the importance of investing new capabilities to capture growth opportunities.

4.2 Perceived uncertainty and narrow framing

Section 4.2 starts with examining the general concept of perceived uncertainty and related empirical studies, followed by illustrating the behavioural decision concept of *diminishing sensitivity to uncertainty.* Then this section discusses how the narrow framing effect explains firms' exploitation focus.

The effect of perceived policy uncertainty

To better understand the relationship between organizations and their environment in the context of decision studies, scholars suggest the concept of perceived environmental uncertainty, in which the way decision makers experience uncertainty is emphasized. Three types of perceived environmental uncertainty are proposed: (1) state uncertainty refers to the unpredictability of the environment; (2) effect uncertainty refers to the inability to predict the impact of the uncertainty; (3) response uncertainty refers to the inability to predict the consequences of options responding to uncertainty(Duncan, 1972; Milliken, 1987). Here the investigation of perceived uncertainty is relevant to the definition of "effect uncertainty", referring to the process of how decision makers perceive the impact of the uncertainty.

In some empirical studies, the role of perceived policy uncertainty has been considered as being critical in influencing the firms' investment decisions, particularly in the area of the energy industry sector. Yet findings showed mixed results. On the one hand, studies suggest that policy uncertainty would have negative influence on investment decisions. For example, an study of the Californian wind power industry found that although the government stimulus policy is in place, firms' technological

investments involving long payoff time can be dampened as a result of the expectation of policy uncertainty during a longer time frame (Nemet, 2009). On the other hand, studies show that policy uncertainty may not necessarily have negative influence on investment decisions. In a case study based on the German power generation industry, findings suggest that, from the strategic consideration of securing competitiveness, firms may not delay investment decisions despite perceiving the policy uncertainty of the European CO_2 Emission Trading Scheme (Hoffmann et al., 2009)[36].

In the context of the Taiwanese case firms, while their investment in current capabilities (exploitation) was not dampened by policy uncertainty; the investment in new capabilities (exploration) seems to be influenced by policy uncertainty. Some study suggests that rather than policy uncertainty, it is the "positive income effect" from the deployment policy explains PV firms' focus on exploitation (Hoppmann, Peters, Schneider, & Hoffmann, 2013). However, it is arguable to disregard the effect of policy uncertainty. In particular, the period of 2010 -2011 (which is not covered in this study) happened to be the transition year in PV industry: the industry was characterized by a sharp profit loss and industry downturn. Therefore the "positive income effect" and "reduced pressure for exploration" may not necessarily explain firms' continued investment in exploitation during this period.

While taking into account the influence of perceived policy uncertainty, this research argues that the general concept of perceived uncertainty employed in previous studies

[36] Both cases could be explained by the real option theory with different assumption of uncertainties. In the first case, policy uncertainty can be categorized as the "input cost uncertainty" which is exogenous to the firm. As there is no way to reduce the uncertainty, a feasible strategy is to postpone the investment until more confirmed and favourable market signals are received. In the second case, policy (regulatory) uncertainty could be explained by the category of uncertainty that could be reduced and create pressure for increasing investment to enhance competitiveness.

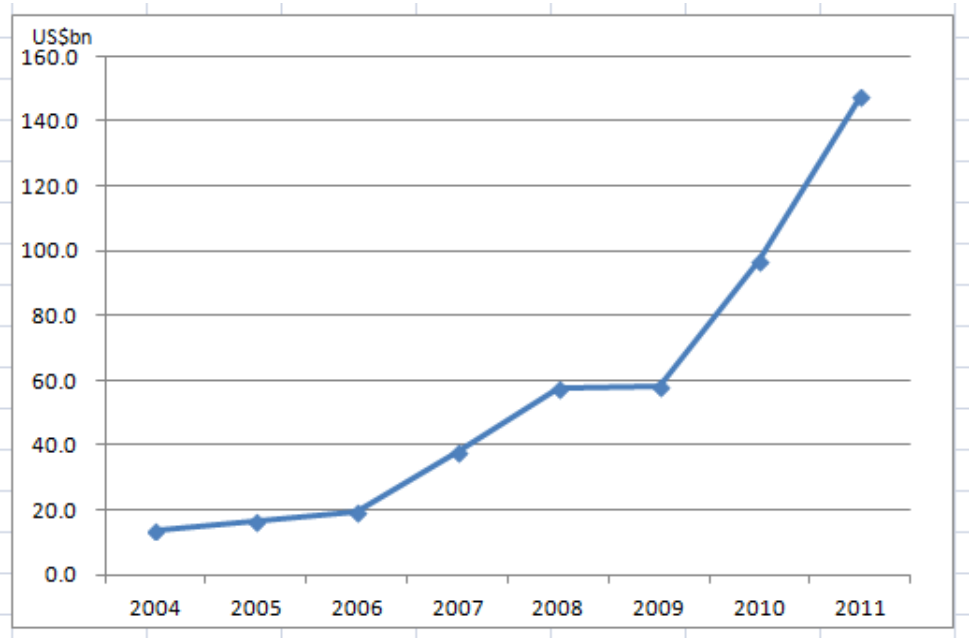
may not be sufficient in explaining firms' investment behaviour. It suggests that the concept of *diminishing sensitivity to uncertainty* may better explain the influence of temporal pattern of uncertainty and the less-than-estimated effect of policy uncertainty on PV firms' investment decisions.

Diminishing sensitivity to policy uncertainty – General finding from the global PV investments in the period of 2004-2011

Drawing on the concept of *diminishing sensitivity to uncertainty* from behavioural decision theory, the *pattern* of uncertainty in influencing the perceived prospect may explain the perceived impact of the government incentive policy on overall PV industry investments in different periods. In the period 2005-2008, the implementation the FiT program triggered the first investment boom of the PV industry. At this point the incident turned from *impossibility* to *possibility* (the first official launch of FiT in Germany in 2005 and following adoptions in other EU countries), in a manner in which the influence on the perceived prospect was expected to be significant (Kahneman, 2011; Tversky & Fox, 2000). Historical data witnesses the substantial impact on new investments in the early industry growth period. Then the first industry downturn and the incident of policy uncertainty during 2008-2009 showed a negative influence on the growth of new investments. Then in late 2010, policy uncertainty of further incentive cuts were announced, but this time new investments in the global PV industry were not affected (Bloomberg, 2012)(**Fig. 4.7**). Applying the effect of diminishing sensitivity to policy uncertainty, the second industry downturn (the period of 2010-2011) marked the point at which the incident was perceived more probable on the basis of previous reference points (i.e. earlier incidents of policy cuts in 2008). Thus at the point where the incident simply move

from probable to more probable, the influence of policy uncertainty on the perceived prospect can be less significant compared to the experience started from zero.

Fig. 4.7 Global new financial investments in solar technology 2004-2011



** Solar technology includes solar thermal and PV; solar PV accounts for the bulk of the investment.*

** Global new financial investment includes investment from VC, Government R&D, Corporate R&D, Private Equity, Public market and Asset finance.*

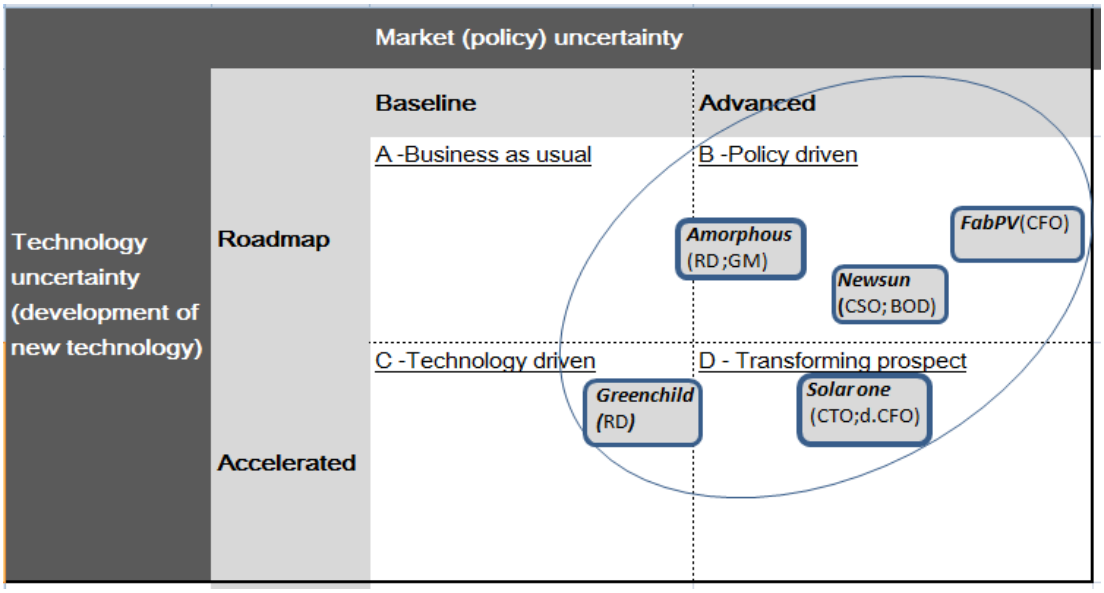
Source: Bloomberg New Energy Finance, UNEP.

Diminishing sensitivity to uncertainty –Scenario evaluation of Taiwanese PV firms

In the context of Taiwanese PV industry, the concept of *diminishing sensitivity to policy uncertainty* is illustrated by the scenario evaluation of Taiwanese case firms. Firstly, the interview data from the scenario evaluation shows a convergence towards the policy driven scenario in the next five years (**Fig**. **4.8**). While senior managers had slightly different views on the development pace of the emerging technologies, the

majority of them agreed that the policy force would be relatively stronger than the force of technology in driving the PV industry, on the grounds that emerging technologies would still be faced with the commercialization issue in the next few years. This perspective reflects the facts of industry development in the past few years, and most senior managers assumed that such trends would be continued in the next five years.

Fig. 4.8 Scenario result for the five firms



Source: interviews and compiled by the author.

However, when being asked about the effect of policy uncertainty, these senior managers similarly expressed that neither government incentive nor environmental related policies would affect the firms' decisions in new capability investments. As described by *Greenchild*'s R&D Head:"although policy uncertainty may influence our business, it would not affect our investment in new technologies". Similar remarks were received from most senior managers. This seemingly conflicting view reflects their experiences with the uncertainty of government support policies. These

interviewees agreed that government incentive programs had been critical to the PV industry and would continue to have an impact on the market. But after the ups and downs of the past few years, they realized that the uncertain nature of government support policies would be inevitable for the PV industry. As the *Solar one* CTO and *Amorphous* R&D Head commented:"policy uncertainty is expected in the next few years".

Some scholars have argued that the expectation of future policy (e.g. the direction of environmental policy) rather than current incentive measures, may have a positive impact on firms' innovation investments, because firms' decisions can be based on the prospect of future policy rather than today's valuation price (Popp, Newwell, & Jaffe, 2010). However, in this research, senior managers expressed different views on the expectation of future environmental policy. For example, while *Solar one*'s senior managers described the optimistic prospect of environmental policy, *Amorphou*s' senior managers showed relative pessimistic attitude towards the development in the near future. The influence of expectation effect of future policy is not evident among senior managers of these case firms. The finding here is more consistent with the explanation from the concept of *diminishing sensitivity to uncertainty*: the perceived effect of uncertainty is influenced by decision makers' adjustment of the reference point derived from previous experience (Kahneman, 2011; Tversky & Kahneman, 1974).

Both global PV investment trend and Taiwanese PV firms' scenario evaluation illustrate that, the concept of diminishing sensitivity to policy uncertainty may explain senior managers' perceived less effect of policy uncertainty on investment decisions. Next, this research further argues that the root cause influencing the decision of

capability investments may lie in these Taiwanese firms' (represented by senior managers') confidence about the most plausible way to seize the market opportunity, despite the experience of uncertainties (Starbuck, 2009).

Narrow Framing

Drawing on the behavioural decision concept, narrow framing effect refers to that choices and decisions are limited by heuristic judgments or certain perspectives (Kahneman, 2003b; Tversky & Kahneman, 1986).

Optimistic forecasts

These senior managers showed an over-optimistic attitude about the market forecast and overestimated the potential growth through production expansion. Firstly, during the scenario interview, most managers favoured the advanced policy scenario with the assumption of strong market growth (which is indicated by their choice leaning towards the right hand side of the scenario table). Although recognizing current gloomy economic condition, these senior managers generally expressed optimism about future market growth. With this optimistic view about the potential of PV, none of the senior managers mentioned that the possibility of accelerating PV industry structural change would similarly imply threats under the overall growth outlook; for example, the competition from other renewable energy sources and new competitors in the PV industry, or protection policies in different countries[37]. Basically, these managers considered that the possibility and the potential impact of these variables were unlikely to be significant in the near future. With this perspective, these senior

[37] Specifically, over 95% of Taiwanese PV cells are exported.

managers seemed to emphasize more on the prospect of overall market growth than on the opportunity resulting from possible industry structural change.

Secondly, despite signs of over capacity in the c-Si value chain since 2009 (**Table 4.3**) (ECJRC, 2009; EPIA, 2011), historical data shows that the three c-Si firms had continued their production expansion during 2009-2010. Indeed, these firms had enjoyed a very profitable period in 2010. Yet the catastrophe of plummeting ASP (Average Selling Price) started soon after in 2011, and the over-supply situation has accelerated with sharply increased capacity from Chinese PV firms. If based on the conservative policy scenario, PV market growth might be stagnant (EPIA, 2010, 2011). Even with the optimistic policy scenario, the capacity would still be far beyond the expected market size. Further, judging from the unutilized capacity from Chinese PV firms, it would be reasonable to expect continued pricing pressure. The downward trend of both ASP and profit margins has appeared to be irreversible since the first signs of trouble in 2008 (Bazilian et al., 2012).While these senior managers are familiar with the market forecast numbers and aware of the oversupply situations, they are convinced that their core capabilities (such as cost reduction through the advancement in cell structure/material and relevant manufacturing processes) is key to survive in the changing market environment.

Table 4.3 PV Cell Production Capacity as of 2009

	c-Si				Thin film
	Polysilicon	Ingot/wafer	Cell	Module	Total
Production capacity	130,000 Tonnes	15GW	18GW	19GW	2GW
Effective capacity	90,000 Tonnes	10GW	9GW	7GW	

**: In 2009, the market (installation) is around 7GW, In 2010 the market is around 17GW and the production is around 24GW. In 2011, the market is around 28GW. It is estimated that the production capacity may reach 80GW by end of 2012, which is far more than the most optimistic scenario.*

Source: (ECJRC, 2009; EPIA, 2011), data compiled by the author.

In the interview, these senior managers suggested that as more "weak" PV cell/module firms exit the market, those that survived would capture the market growth; they also suggested that Taiwanese first tier PV firms[38] are generally more competitive in terms of PV cells' price/performance ratio than their Chinese counterparts[39]. As described by *FabPV*'s CFO, "the situation of over capacity actually includes the estimation of the so-called invalid stock produced by second tier firms; and only the high performance product will be in demand." However, these senior managers may potentially underestimate the volume of the quality cells produced by the first tier Chinese firms [40] and overestimate the market's demand for premium-priced high performance products. Moreover, from the perspective of end customers, even Taiwanese PV cell firms may excel in the quality and efficiency performance, but, such slight advantage can be significantly diluted in the PV cost

[38] The first tier Taiwanese PV cell firms here refer to the top 5 Taiwanese cell firms in terms of the capacity data (PV cell production volume). As of 2010, there are total 33 PV cell firms (including 15 c-Si firms). The three c-Si case firms in this research are among the top 5.

[39] Excepting the ITRI deputy director, other third party industry stakeholders expressed the same view.

[40] The definition of the first tier Chinese PV firms is also in terms of the capacity data (production volume) based on the worldwide PV cell production data. Thus here the first tier Chinese PV firms are those among the worldwide top 10 firms. With this definition, only *Solar on*e and *FabPV* are among the worldwide top- 10 list. As of 2011, there are total five Chinese firms among the worldwide top 10(Table5.2). Some first tier Chinese PV cell firms surpass Taiwanese peers in terms of cell production volume and the scale of vertical integration (upward silicon production or downward module assembly).

structure and the amortization of PV project life times from the calculation of LCOE.

These senior managers' judgment of the competition and the market for their current products can be explained by the heuristics utilized in the judgment process, particularly the *representativeness heuristic* (Tversky & Kahneman, 1974). The resulting bias in overconfidence shows in that these senior managers were highly sensitive to the *extremes* or the "*representativeness*" of the incidents. For example, the short industry recovery in 2010; the impression gained from some Chinese second tier PV firms[41] and the recent anti-dumping policy against Chinese firms in the US and EU. On the other hand, they may not be sufficiently sensitive to the *variation* and the *predictability* of these "representative" events as the basis for judgment (Griffin & Tversky, 2002). As these interviewees possess the knowledge of the context and did not report high level of perceived uncertainty, the judgment is not necessarily resulting from lacking of information in the decision context, but is subject to the process of *attribution substitution* in which environmental uncertainty is not a necessary condition for the occurrence of heuristic judgment (Kahneman & Frederick, 2002)[42].

Isolating effect in project evaluation

The tendency to isolate the uncertainties and future opportunities in the overall impact assessment is illustrated by the findings of senior managers' evaluation of new

[41] Here the definition of second tier Chinese PV firms generally refers to those that are not among the top 10 worldwide PV firms. As of 2011, there were more than 100 PV cell firms in China (ECJRC 2011).

[42] As discussed in Chapter 2, *attribute substitution* refers to that decision makers "assess a specific target attribute by substituting a related heuristic attribute that comes more easily to mind" (Kahneman 2003b: 707).

investment projects. While expressing the view that all the prompted factors would be taken into consideration, these senior managers similarly indicated the factor of "market potential" as the most important criterion, followed by the factor of "expected revenue stream" (**Table 4.4**). At the first sight, the result appears to suggest that these managers are aware of the importance of future market opportunities in selecting projects. But the issue here is the *judgment* as to the timing and the level of impact. As discussed earlier in scenario analysis, their judgment of "market potential" is based on the most probable scenario with the assumption of optimistic incentive policy measures. This basis of judgment may overlook the possibility that investment decisions in new capabilities sometimes need to be based on the less probable scenario to take into account uncertainties, because profits may arise from "true uncertainties" (Freeman & Soete, 1997a; Knight, 1971). The assessment of "expected revenue streams" reflects the propensity towards the short-term measurement for investment projects. For example, in this research context, most senior managers mentioned that their firms usually use indicators such as ROI or payback period for assessing investment projects. These commonly used financial models for new investment evaluation can be biased in favour of projects with certainty (Bowman & Moskowitz, 2001; Kogut & Kulatilaka, 2004).

Table 4.4 Evaluation Criteria for Selecting Investment Projects

	Criteria for investment project selection	
	Probability of technical success	
	Probability of market success	
	Development costs of the project	
	Development time of the project	
1	**Market potential**	8 of 8 senior managers rated "the most important"
2	**Expected revenue stream**	*6 of 8 senior managers rated "the second most important"
	Payback period/break even	
	Internal knowledge/competence building	

** Except Greenchild's RD, who rated "payback period" as the second important; Amorphous' RD, who rated "probability of technical success" as the second most important.*

Source: Interviews, compiled by the author.

In the context of increasing price competition on c-Si cell/modules, the prospect of gain from c-Si- firms' current product platform could be possible; but it is also clear that this possibility could be low. According to the advanced prospect theory, risk-seeking behaviour is observed for the "*hope of larger gains*" (Kahneman, 2011; Kahneman & Tversky, 1992). In view of the over-supply trend, the investment of capacity expansion is a sign of *risk-seeking* behaviour. Although in this research context those projects related to process and efficiency improvement may not necessarily be categorized as "risk-seeking", the emphasis on investing in current capabilities shows the willingness to continue betting on the prospect of gain even with the low probability of success.

On the other hand, comparing to the investments for current capabilities, new capabilities investments such as projects for developing new technologies or solutions are usually smaller in size. Therefore the potential loss from the new capability investment project is expected to have less impact on the overall revenue stream.

However, even with the prospect of a low probability of loss compared with the investments on current capabilities, the *risk-averse* behaviour towards these smaller-sized projects can be explained as the "*fear of larger loss*" in view of the loss resulting from the investment on current platform (Kahneman, 2011; Kahneman & Lovallo, 1993). Within this decision frame, the potential of gains from investing in new capabilities could be underestimated.

Summary

Firstly, Section 4.2 discusses that the commonly used concept of perceived environmental uncertainty may not sufficiently explain firms' investment decision. The concept of diminishing sensitivity to uncertainty is proposed as a more refined concept of perceived environmental uncertainty. This concept also demonstrates that the level of perceived uncertainty may not necessarily be a valid indicator in explaining firms' decision behaviour. Section 4.2 argues that the root cause of exploitation focus lies in narrow framing effect in the heuristic judgment process. Specifically, this analysis of narrow framing is illustrated with two empirical investigations. The first is the propensity of optimistic market forecasts: these senior managers showed an over-optimistic attitude about the market forecast and overestimated the potential growth through exploitation investment. The second is the tendency to isolate the uncertainties and future opportunities in the overall impact assessment for new investment evaluation. The analysis shows that with the inclination of using short-term measurement for investment projects, the potential prospect of gains from exploration investments could be underestimated in the evaluation process.

4.3 Institutional experience effect

Section 4.3 examines how the institutional environment creates specific influences on forming the prevailing frame among Taiwanese PV firms. It starts with assessing the influence of demand-pull and technology push policy in Taiwan. Then, it illustrates an investigation on narrow framing effect – senior managers' framing of the Specialized Human Resources Issue. This section concludes with the discussion of prevailing frame and experience effect.

Assessing the Influence of demand-pull and technology- push Policy in Taiwan

The reason for a consolidated discussion on the influence of policy in the Taiwanese institutional context firstly lies in that scenario evaluation analysis shows a convergence trend on the policy – driven scenario. Secondly, while the definition of "policy" in scenario evaluation refers to demand –pull policies, the reason for examining technology-push policies is that one of the selection criteria of these Taiwanese case firms is based on the participation of MOEA program, a major technology- push policy mechanism in Taiwan.

The influence of demand-pull (government incentive) policy

Given the strong orientation of export-led production of these Taiwanese PV cell firms, it is obvious that senior managers' conception of government incentive policy focuses on the overseas market. In 2012, Taiwanese PV firms produced 12.5 % of annual worldwide PV cell/module production. But the accumulated PV installation in

Taiwan only accounts for around 0.14% of the worldwide PV cumulated PV installation. In fact, Taiwanese government initiated the "Renewable Energy Development Plan" since 2002. Later, the government approved the incentive measure (FiT) based on the "Renewable Energy Development Act" in 2009. Later, the government further announced the new "Million Solar Rooftop Program" with an aim to boost the installation capacity (ECJRC, 2010, 2013). However, the effect of the government demand pull policies including FiT incentive and procurement programs has not proved significant effect in inducing domestic PV installation in Taiwan.

The reason why the Taiwanese FiT may not work as effective as the German FiT implies a global issue in the PV market – the infrastructure problem. For example, one of the key indicators of PV adoption is grid parity, of which the comparison is associated with the price of local electricity generated from conventional energy sources. Thus it would be more difficult for PV to achieve grid parity in countries with lower electricity price[43]. Comparing with other Asian countries, Taiwan has relative lower electricity price[44]. Further, Taiwan's utility provider (Taiwan Power Company) remains as the dominant state-owned enterprise. Therefore, although the feasibility and economic benefits of PV have been demonstrated in many market sectors, the policy issue is not only the implementation of government incentive measures, but also the battle of transforming the longstanding infrastructure built for the incumbent energy source/utility providers (EPIA, 2011; Lovins & RMI, 2011).

For the case of Taiwanese PV firms, it is obvious that the effect of foreign demand pull policy is stronger than domestic demand pull policy; as suggested in the findings

[43] IEA data (2012) suggests that high fossil fuel subsidies have been provided in many countries.
[44] IEA data (2013) suggests that Taiwan has the second lowest residential and industrial electricity price among Asian countries.

of some cross-country study in the PV industry (Peters, Schneider, Griesshaber, & Hoffmann, 2012). Given the fact that incentive policy measures are inevitably influenced by local governments' economic and political situation, PV firms' reliance on importing countries' incentive program may not necessarily be a sustainable business model. For example, the German FiT policy has faced with the skeptics' criticism of subsidizing foreign PV cell/module companies with tax-payers' money. Although others argued that German equipment providers and system integrators also benefit from low-cost PV cells/modules (EPIA 2011), the opposition to Chinese PV cells/modules was emerged in 2012 (Hoppmann et al., 2014). For Taiwanese PV firms and investors, the sense of lacking of control over policy uncertainty (from other governments) may encourage the opportunism for chasing short-term gains[45].

The influence of technology-push (government R&D funding) policy

From the perspective of global PV industry, public R&D investments have contributed significantly in the PV technology development in the 1970s and 1980s (Bradford, 2006; Breyer et al., 2010). Yet public R&D investment has played a much less significant role than corporate investments since the past decade[46] (Bloomberg, 2012; Breyer et al., 2010). Still, when interviewed, most of the senior managers suggested that academia and government research institutes should lead the investments in basic research for PV technologies and that the link with research communities should be critical for the firms' new technology development. In the context of Taiwanese PV industry, the discussion of technology-push policies focuses

[45] For example, risk-seeking behaviour with low prospect of gains such as capacity expansion under policy uncertainty as discussed in Section 4.2.

[46] In 1980, public R&D investments (estimated by international PV patent families) accounted for around 70% of the total PV R&D investments of which less than 30% were from the corporate. And in 2005, more than 90% of the PV R&D investments were funded by the corporate (Beyer et al. 2010).

on government sponsored “R&D Innovation Program” provided by MOEA (Ministry of Economic Affairs).

The reason why MOEA’s R&D Innovation Program is a flagship technology-push policy firstly lies in the scale of funding - the MOEA Innovative R&D program is the most generous government funding scheme for technology firms in Taiwan. **Table 4.5** shows the project budget and funding scale of the five case firms’ MOEA projects. As the design of the MOEA R&D innovation projects aims to stimulate firms’ exploratory investments, the “innovativeness” of the technology to be developed in the projects is served as the basis of evaluation criteria for awarding the government funding. This program is characterized by the rigorousness of the evaluation process: after passing the initial assessment, firms’ proposals are required to be reviewed several times by the evaluation committee consists of government officials and referees from academia. Secondly, this program “implicitly” encourages the link with research communities: usually, collaboration plans with academia and research institutes proposed in the MOEA projects are highly valued in the application assessment process.

Table 4.5 MOEA project time line and budget

	MOEA projects	Program	Project timeline	Total project budget (GBP)*	Govt funding (GBP)*	Funding percentage
Solar one						
	A1-Polysilicon wafer manufacturing	ITDP	Jul. 2009-Jun.2011 (24 months)	£ 2,722,140	£ 900,180	33.07%
	A2-High efficiency cell (emitter)	ITDP	Apr. 2011-Mar.2013 (24 months)	£ 1,830,860	£ 732,340	40.00%
	A3-Next generation cell structure	ITIC	Apr. 2011-Mar. 2014 (36 months)	£ 992,240	£ 280,000	28.22%
Greenchild						
	D1-Polysilicon wafer manufacturing	ITDP	Apr. 2008- Dec. 2009(21months)	£ 999,800	£ 300,000	30.01%
	D2-CIGS pre-study	ITDP		**	**	**
	D3- CIGS development	ITDP	2011-2015 (5 years)	£ 13,000,000	£ 2,000,000	15.38%
FabPV						
	E1- High efficiency cell (material)	ITDP	Jul. 2008-Jun. 2010 (24 months)	£ 1,401,640	£ 560,660	40.00%
Amorphous						
	B1-a-Si/uc-Si and BIPV application	ITDP	Aug. 2009- Jul. 2011 (24 months)	£ 1,200,000	£ 552,000	46.00%
	B2- CIGS pre-study	ITIC	Aug. 2009-Jul. 2012 (36 months)	£ 649,760	£ 298,000	45.86%
Newsun						
	C1- CIGS manufacturing	ITDP	May 2011- Oct. 2012 (18 months)	£ 1,400,000	£ 500,000	35.71%
	** The exchange rate NTD to GBP = 50:1*					
	***data not available*					

Source: MOEA, data compiled by the author

However, it seems that the mechanism of MOEA's R&D Innovative Program may not necessarily work effectively to encourage firms' exploratory investments in many cases. In this research context, the majority of PV firms' projects were targeted at the firms' current technologies (please see **Table 4.2** in Section 4.1). There are two possible explanations. Firstly, it is not evidently difficult to utilize MOEA projects as a source of funding support for firms' current R&D projects; particularly for those firms with related experience have always been familiar with the operating rules for applying funding from this program. Although matching new investments/funding from the firms are required, most firms are skilful with ways of how to leverage their current resources for MOEA projects[47]. The additional government funding can then be used for hiring new people and equipment. For some firms, these new hires and equipment may also be utilized for firms' internal projects other than the MOEA projects.

[47] Informal interviews with several experienced MOEA proposal counsellors.

Secondly, it is the mechanism of KPI (Key Performance Indicator) for measuring the output of the MOEA projects. Apart from patent applications (usually filed in Taiwan), estimated production value (e.g., the projected sales or market value derived from the MOEA projects) are the most common and important indicators. While these KPIs emphasize the substantial evidence to justify government's investment funding, the mechanism could discourage firm to invest in exploration because it would be much easier to demonstrate near-term evidence for investment projects based on current capabilities.

With respect to the link with research community, although MOEA projects are designed to encourage collaboration between the firms and the research institutes, the reality of the limited cooperation is due to the firms' concerns over confidentiality and project ownership. In particular, there is an infrastructure issue of government-sponsored research institute such as ITRI (Industrial Technology Research Institute)[48]: although one of the goals of the research institute is to facilitate knowledge and technology transfer with the firms, the research institute also has its own goal in producing new technologies and creating new ventures. This may creates the sense of potential interest conflict in the collaboration between the firm and the research institute[49].

Framing of the specialized human resources issue

In responding to factors with respect to resources that may affect their firms' decisions in capability investments, senior managers similarly expressed the view that shortage

[48] ITRI is the largest government research institute in Taiwan. ITRI has been regarded as the incubator for many high-tech firms in Taiwan.
[49] Interviews from senior managers and ITRI (MOEA project leaders).

of technology talents and skilled engineers influences the firms' investments in developing new capabilities. Firstly, they claimed that talent competition from the related industries, particularly the semiconductor industry is a serious issue. These senior managers described that since the downturn in 2011, the PV industry has experienced the pressure of losing technology talent. The reasoning is that as stock options and awards are usually the major parts of the total compensation package for RD talents in Taiwanese high-tech firms, the suddenly plummeted stock price of these Taiwanese PV firms in 2011 (compared with their soaring price during 2008-2010) contributes to the outflow of technology talents and skilled engineers in 2011.

However, the data from R&D expense[50] shows that, in comparison with the leading firms in the Semiconductor and TFT-LCD industry[51], the three c-Si PV firms generally invested at a lower level both in 2010 and 2011[52] (**Table 4.6**). The two semiconductor firms allocated the R&D expense as high as around 8% of total sales. And, despite similarly experiencing industry downturn and losses as the PV firms, the two TFT-LCD firms kept R&D expense stable at 2% in 2010 and 2011. As for the three c-Si firms (excepting *Greenchild),* both *Solar one and FabPV* invested in a much lower level of R&D than TFT- LCD firms, even during the very profitable year of 2010. Therefore the finding from R&D Expenditure suggests that the talent shortage issue claimed by the senior managers may not necessarily result from the labour market's perceived outlook of the PV industry, but from these PV firms' wiliness to retain technology talents and invest in new hires.

[50] In these firms, R&D expense refers to payroll for R&D staff, and does not include the purchase of specific equipment or system in the R&D department.

[51] There are similarities in the required skills and experiences of R&D people in the three industry sectors.

[52] As *Solar one, FabPV* and *Greenchild* are regarded as the top technology-leading and R&D intensive firms in the PV industry, the comparison of R&D expense is conducted with the top two firms in the Semiconductor (manufacturing focus) and TFT-LCD industries.

Table 4.6 R&D Expense Comparison among Three c-Si firms and Leading Firms in the Semiconductor and LCD Industries in Taiwan

	TSMC	UMC	AUO	Chimei	*Solar one*	*Greenchild*	*FabPV*
Industry	Semiconductor (manufacturing)	Semiconductor (manufacturing)	TFT -LCD	TFT -LCD	PV	PV	PV
R&D expense (% of Sales)							
2011	8.00%	8.17%	2.00%	2.00%	1.14%	5.10%	0.54%
2010	7.00%	7.11%	2.00%	2.00%	1.28%	2.71%	1.00%
EPS							
2011	$5.18	$0.84	-$6.94	-$8.81	-$5.61	-$10.16	-$7.76
2010	$6.24	$1.91	$0.76	-$2.09	$12.30	$1.74	$11.55

Source: the firms' annual reports, data compiled by the author.

Secondly, the five case firms' senior managers specifically indicated the issue of lacking skilled engineers on PV application products and system design(MOEA, 2011). Generally, these managers suggested that the shortage of product design developers or engineers in Taiwan's labour market is closely linked to the ill-equipped infrastructure for solar PV adoption in Taiwan. Quoting from *Solar one*'s CTO:"As PV technologies are characterized by applications, the talents in product design-related technologies need to be cultivated in the usage environment, as in the case of Japan or Germany". However, despite the low PV installation in Taiwan, these PV firms could have the choice to develop related capabilities from working with partners from abroad, particularly given the fact that their predominant market share is not based on the domestic market.

From these senior managers' comments about the factors limiting their firms' new capability investments, the reason why these firms were not actively engaging in new capability development was generally attributed as a common resources issue of talent

shortage in the industry and institutional environment. Here the judgment process can be illustrated in the model of *attribute substitution* in which decision makers may answer an easier question with more accessible heuristics (such as the *representative* and *availability* heuristics) to substitute the attribute of a complex decision problem(Kahneman, 2003b; Kahneman & Frederick, 2002). Firstly, in the claim of talent resource competition from other related industries, the comparison of perceived industry outlook with the semiconductor industry was served as an immediate instance to construct the possible correlation between the profitability and the availability of technology talents for the firms to develop new capabilities. Yet the claim was not validated based on the R&D expense comparison with another related industry (employing technology talents with similar skill sets) suffering worse downturn in 2010 and 2011. Secondly, in the claim of lacking infrastructure environment to cultivate technology talents, the perceived shortage of a specific category of skilled labour (such as PV system design) in the local market was substituted as the reason for insufficient investments in new technologies or applications: but this statement was not that in line with these firms' need and planning in expanding global markets. In reality, these firms simply may not have the plan to hire PV application and design engineers from local market as much as they claimed.

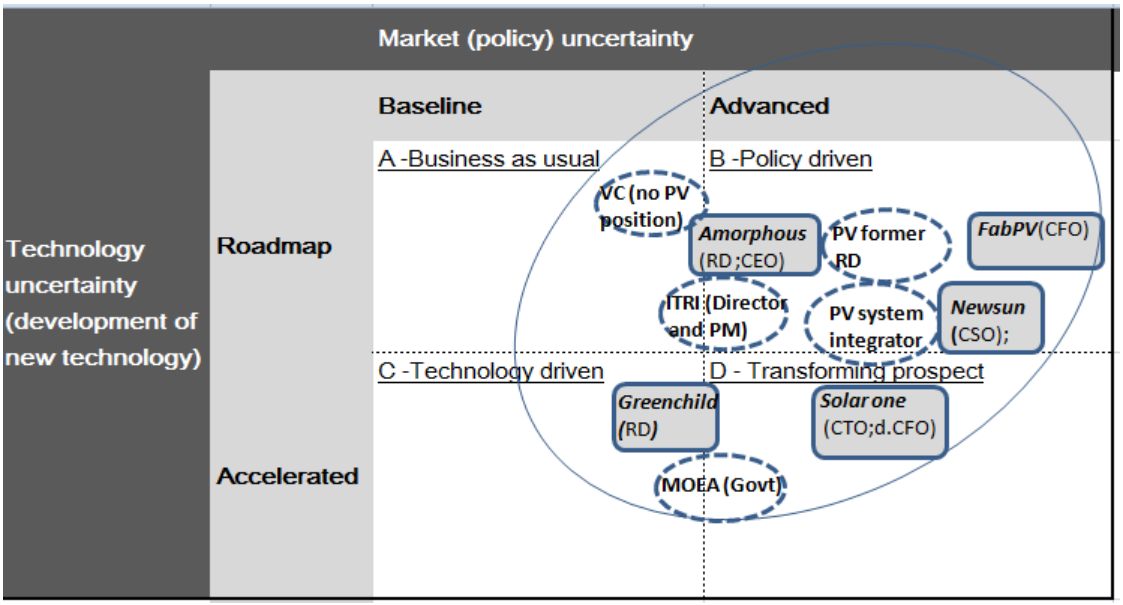
The prevailing frame and experience effect

From the scenario interview, besides the converged view towards the policy driven scenario(**Fig. 4.9**), all the interviewees (including the third party stakeholders) expressed the similar perspective that Taiwan's manufacturing and technological capabilities in the electronics and semiconductor industries have been competitive

advantages in the PV industry (Lin & Hsu, 2011; MOEA, 2010): in particular, the consensus is on the ground that it is reasonable to expect that management and knowhow of the manufacturing process in these industries can be successfully applied in the PV industry. In fact, the vast majority of PV firms in Taiwan has indeed inherited background assets from these related industries (WealthPress, 2005, 2009). Not only engineers and middle managers, but also senior managers are usually equipped with the relevant experience in the related industries. The influence of such professional experience on high-level management is as described by one VC interviewee: "The owners of most Taiwanese PV firm are basically running the PV business with the same mode for their electronics or semiconductors business." The VC interviewees and the ITRI interviewee (deputy director) similarly suggested that the Taiwanese PV industry's tendency of focusing on manufacturing has been rooted in the prevailing success model that the electronics and semiconductor industries have been using for decades[53].

Fig 4.9 Scenario Result (with third party stakeholders)

[53] The influence of professional knowledge and experience in the institutional context is also reflected in the perspective of institutional theory. To some extent, the prevailing frame of manufacturing excellence corresponds to the notion of concept of institutional logic (DiMaggio & Powell, 1983; Thornton & Ocasio, 1999).



Source: interviews, compiled by the author.

These interviewees were knowledgeable about the fact that as the PV industry grows; the characteristics of PV further differentiate its development with the trajectory of the electronics or semiconductor industries. It is not because of their lack of awareness but because of their past successful experience strengthens the mindset of overconfidence in current capabilities: indeed, the rapid growth of these Taiwanese PV firms during the past few years can be attributed to applying the best practices from the related industries in Taiwan. While these senior managers and the third party stakeholders perceived that the technological and manufacturing excellence inherited from the semiconductor and electronics industries has been the competitive advantage for the Taiwanese PV firms, such capabilities and experience may constrain these firms' framing of plausible ways to capture future opportunities (Levinthal & March, 1993; March, 2010). Although these competitive advantages and experience are still important, the issue is whether these capabilities can really address the future development in the industry. The "dilemma of competitive advantages" refers to as that whereas the competitive advantages may enhance the current performance, it also

increases the cost of developing new capabilities and "competing for primacy" (March, 1994: 252).

Heuristic bias

These interviewees' similar pattern in framing the scenarios and contingencies can be explained by the process of heuristic judgment in using the *availability heuristic*. Here availability heuristic refers to the ease of recalling the best practice accessible in the industry and the institutional environment. Thus the judgment based on successful experience is susceptible to the biases derived from the familiarity and salience of the instance, as well as the ease of constructing the correlation (March, 2010; Tversky & Kahneman, 1974). In addition, the influence of heuristic judgment based on successful experience is related to the *endowment effect* of which the propensity of overestimating the value of owned assets and current capabilities is demonstrated(Kahneman et al., 1991). The process of heuristic judgment is stressed in the "*moment-based experience effect*" (Kahneman & Tversky, 2000), suggesting that it is easier to make quick judgment based on immediate examples, and that it is relatively difficult to make rational assessment of current possessions (assets) envisioned in different scenarios or context.

Perspective bias

With respect to the *accumulated experience effect*, it stresses the role of *belief* in influencing the judgment and decision process. The *competence effec*t suggests that decision makers are more willing to bet on areas that they feel more in control of on the basis of prior belief (Heath & Tversky, 1991; Starbuck, 2009; Starbuck &

Milliken, 1988; Tversky & Fox, 2000). For example, c-Si firms' senior managers and third-party interviewees appeared to be confident in the firms' capabilities in existing technologies (i.e., they showed the sense of control over this source of technology uncertainty). But as discussed earlier in Section 4.1, although the technological progress of c-Si PV cells can be predictable to certain degree, the elements of associated commercial uncertainty such as the silicon cost and industry structural change can be overlooked.

Further, this research context, the *prevailing frame* constructed from successful experience can also be traced from interviewees' shared perspective of using the rationale of "national competitive advantages" in perceiving the potential and direction of capability development in the institutional context. The commonly held assumptions such as the sustainability of competitiveness and the timing for new opportunities could be susceptible to the *perspective bias* derived from the long-term experience. Moreover, the seemingly rationality-based decision model such as the national competitive analysis(MOEA, 2010; Porter, 1980, 1990) may just serve as the tool in narrowing and justifying decision makers' perspectives.

Summary

Firstly, the assessment of the demand-pull and technology-push policy in Taiwan suggests that both policy measures are not necessarily influential on Taiwanese PV firms' capability investments. Secondly, following the line of argument on narrow framing effect in influencing these firms' exploitation focus, this section illustrates a resources framing issue of capability investments in the institutional context of Taiwan. At the first sight, senior managers' comments that shortage of technology

talents limits the firms' new capability investment appears to be reasonable from a common sense. But the analysis shows that these claims are not validated. Senior managers' statements demonstrate the heuristic judgment process of attribute substitution. Thirdly, further advancing the argument that industry and institutional experience reinforces narrow framing effect, this section concludes that the prevailing frame – in particular the influence of best practices and successful experience explains Taiwanese PV firms' exploitation focus.

<Appendix 1> c-Si cells c-Si cells manufacturing process

Compared with the cell integrated thin film modules, c-Si cell/modules have more complex supply chain in the upstream manufacturing process. These steps include: (1) converting raw silicon to solar-grade silicon; (2) second, forming the ingots, the solid block of polysilicon; (3) slicing ingots into wafers; (4) transforming the wafers into cells through wafer surface treatment, p-n junction creation, coating deposition and metallization; (5) connecting and coating to form modules (EPIA, 2011). On the other hand, thin film modules are made by depositing thin layer of photovoltaic sensitive materials on a backing made of glass, stainless or plastic; then the material attached backing is laser-cut into thin cells/modules.

c-Si cells manufacturing process- supply chain

Source : Figure adapted from Solar Generation 6, (EPIA, 2011)

Chapter 5

Selective Attention in the Organizations

Introduction

In addressing the research question: *what is the role of framing in the decision-making process for new capability investment?* Chapter 5 focuses on examining firms' differences in capability investment and selective attention pattern. Here the definition of framing employs the general concept of decision problem interpretation, which is drawing on the concepts of selective attention and attention-based view from the organizational decision perspective.

Section 5.1 examines to what extent selective attention explain variation of capability investment pattern among firms. It starts with investigating the three firms' patterns in capability investments and the presence of selective attention among firms. Based on analysis of firms' investment history and LTS (Letter to Shareholders), Section 5.1 shows that there are mixed findings as to whether selective attention is relevant to firms' variation in capability investment pattern.

In addressing the second research question in this research: "*What factors may influence the role of framing in such process?"* Section 5.2 examines to what extent firm-level characteristics explain variation in selective attention. Drawing on the attention-based view, Section 5.2 employs a comparative analytical view in investigating the two firm-level factors that are critical in influencing firms' selective attention : the first is firm resources (representing firms' economic position), and the

second is firm ownership (representing firms' high- level corporate structure)(Ocasio, 1997).

Section 5.3 starts with examining firms' selective attention from the perspective of key individual decision makers. Specifically, it discusses the influence of *CEO experience* on firms' selective attention and capability investment patterns. Then, in advancing the comparative analysis, Section 5.3 proposes the framework of causal combination view in analyzing the sources of variation and explaining each firm' distinct pattern in different time period.

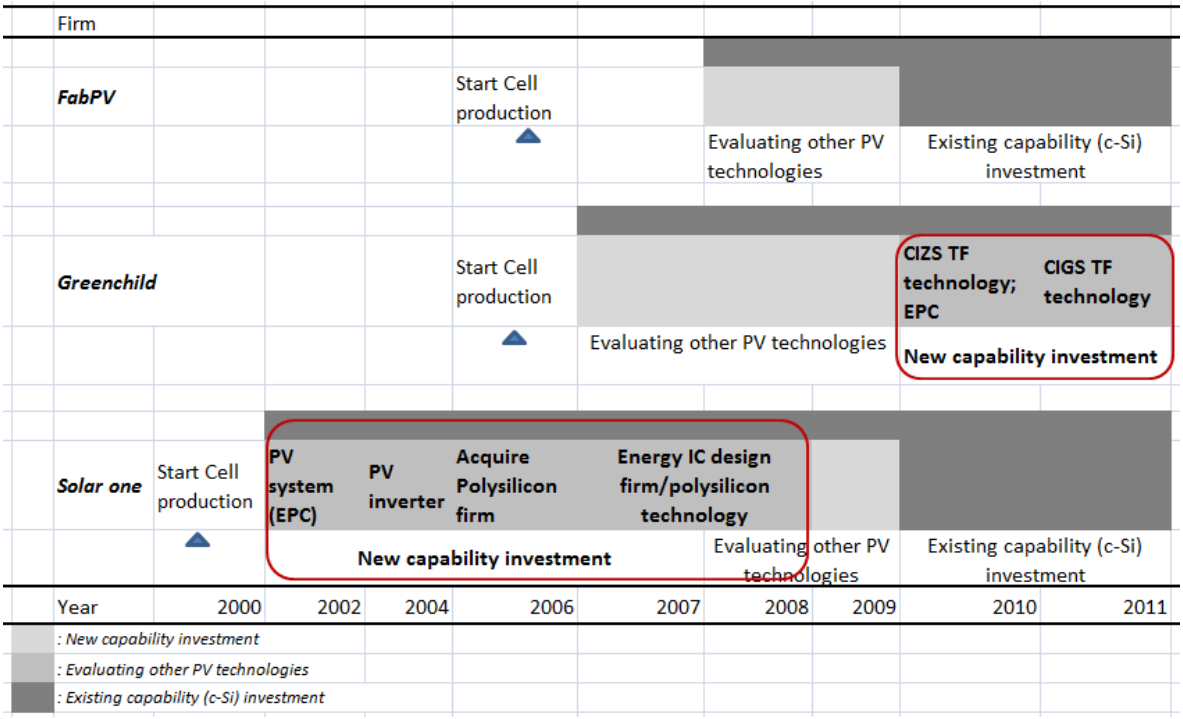
5.1 Capability investment and selective attention patterns

Section 5.1 starts with examining the three c-Si firms' capability investment pattern. Different from Chapter 4's review of the investment pattern in the comparable period 2006-2011, here the investigation includes the period pre-2006 to take into consideration the firm *Solar one's* early investment history. Thus the emphasis is not only on the comparison among the case firms, but also on the in-case comparison of the firm's new capability investment pattern over a different time period.

Investment patterns of the three c-Si firms

In Chapter 4, the similarities in the general direction and timing of the investments were found among the three c-Si firms during the period 2006-2011. Still, certain different patterns are found in the three firms' capability development strategies throughout their investment histories **(Figure 5.1**). Particularly, while all three firms demonstrated an attempt to evaluate other PV technologies during 2008-2010, only *Greenchild* officially invested in the emerging PV technologies (in 2010 and 2011). *Solar one*, a relatively early entrant, was more actively engaged in new capabilities investments during the firm's early period pre-2007 than its recent years.

Figure 5.1 Three firms' capability investments



Source: firms' annual reports and interviews, complied by the author.

Solar one:

Solar one started out as a firm designing and manufacturing testing equipment, and entered the PV industry in 2000. During the period 2002-2005, *Solar one* initiated the PV system integration business line, and the R&D for the PV inverter, the main component in the PV BOS. In 2006, *Solar one* acquired a US-based polysilicon firm. There were some capability investments involved in this acquisition, and the firm continued to make related investments in 2007-2008. In 2007, *Solar one* also set up a new firm targeting energy-saving IC design. There was no official investment into new capability development after 2008, and *Solar one* actually terminated investment funding for the energy IC design firm in 2010. Further, *Solar one* decided to consolidate the PV inverter and system business line and sell the testing equipment (the firm's original business line) in 2011.

The data from *Solar one*'s investment history shows the fact that the firm engaged in

more new capability investments in the first few years after the inception of the solar PV business. After 2006, despite the tendency towards a more focused development strategy based on the PV cell business, there were still several new investment projects. The strategy of being professional PV cell/module manufacturers and focusing on the c-Si technology platform has been clear since 2010.

Greenchild

Greenchild entered the PV industry in late 2004. The firm did not engage in the investment of new capability development until 2010, when the firm announced a partnership with IBM and Solar Frontier to develop CZTS, an emerging thin film PV technology. In the same year, the firm proposed a project to invest in a German power plant. In 2011, the firm invested in a five-year MOEA project in CIGS thin film technology, following an initial pre-study project in 2010. Starting in late 2010, *Greenchild* initiated PV system business investment in the firm's sales office in the US and India.

The firm initially showed its interest in developing alternative PV technologies in 2007. Yet the firm did not officially invest in thin film technologies until 2010. With respect to the new investment in EPC, although *Greenchild* evaluated the proposal to invest in a German power plant in 2008, the firm did not start investing in the EPC business until 2010. In contrast to *Solar one*'s pattern, *Greenchild* focused on the development of c-Si cell/module technology in the firm's early years and started the investments in developing new capabilities later on in 2010 and 2011.

FabPV

Since its establishment in 2005, *FabPV* has been focusing on the development of c-Si

cell technology and has made no official investment in developing new capabilities other than c-Si cell products. Although *FabPV* demonstrated some intent to evaluate alternative thin film technologies, no official investment has been made.

In contrast to *Solar one*, *FabPV* and *Greenchild* were established as c-Si cell manufacturers and entered the market around the same time. Yet the two firms had different investment strategies: While *Greenchild* invested in other PV technologies and EPC businesses a few years after the firm started, *FabPV* has focused on c-Si cell investment since the firm's inception. On the other hand, it appears that *Solar one* and *FabPV* pursued a similar investment strategy focusing on exploiting current capabilities of c-Si -platform since 2010.

Selective attention of the three c-Si firms

Next, the investigation of firm-level selective attention is examined by three firms' Letter to Shareholders (LTS) during 2003-2011[54]. LTS are signed by Chairman (and CEO for some firms) and announced the direction of the firms' most important plans to shareholders. Therefore they are considered as a viable firm-level indicator of the firms' attention towards the environment and responding strategies, particularly for the purpose of collecting retrospective data (Cho & Hambrick, 2006; Eggers & Kaplan, 2008; Kaplan, 2008a; Kaplan, 2011).

Here the analysis of LTS emphasises on capturing the specific description pertaining to *attention towards the environment* and the *responding strategies*[55]. The context of

[54] LTS 2003-2006 only available in *Solar one*.
[55] Most management cognition studies use the quantitative measure of specific word- counts in LTS.

the firms' external environment is categorized by policy and technology uncertainty[56]. Specifically, attention towards the environment examines what issues these firms *focus* on and how they *interpret* the effect. Then the firms' *responding strategies*[57] are compared during the period of 2007-2011[58] **(Table 5.1).**

Table 5.1 Three firms' LTS comparison

[56] Here these firms' internal environment is examined by their sales and EPS (an indicator of profitability) trend of which the pattern is quite similar among all three firms in the comparable period 2006-2011. See Appendix 5-1.

[57] Taiwanese firms' annual reports (with LTS attached) are usually published in the first quarter in the next following year. Therefore the messages on LTS are considered to reasonably reflect firms' strategy in responding to the previous year's environmental change.

[58] Basically there is consistency of style and messages in Solar one's LTS 2003-2006.

		Solar one	FabPV	Greenchild
Attention toward policy uncertainty. (F) - Focus; (I)- Interpret	2003-2006	Fast growing PV demand driven by environmental and incentive policies	N/A	N/A
	2007	(F) positive development on the environmental and incentive policies. (I)strong growth		
	2008	(F) Financial crises influenced credit crunch & incentive policies (I): the 1st time over-supply in PV market	(F) Financial crises influenced PV industry supply chain **(I)opportunity from lower and more competitive PV cost, high demand expected**	(F)Financial crises & dramatic change in Spanish incentive scheme. (I)Supply exceeded demand and fast-dropping cell/module prices.
	2009	(F)incentive cuts . (I) industry downturn, over-supply & price competition.	(F)Financial crises (I) PV industry experienced downturn but "growth under crises" , **Still positive about incentive policies**	(F)Over stock & fast-dropping price. (I)Global awareness in PV , but industry still suffered from cost and pricing pressure
	2010	(F): strong PV demand growth, wide implementation of incentive policies. (I)Industry recover and optimistic trend		
	2011	(F): incentive policy uncertainties triggered by EU debt crises , protection - anti dumping (I)uncertainty in the market demand and challenges- industry downturn		
Attention toward Technology uncertainty. (F) - Focus; (I) - Interpret	2003-2006	no specific , PV industry strong high growth - oil price	N/A	N/A
	2007	(F): silicon shortage; (I): **more players and increased competition**	(F) silicon shortage and rising oil price. (I)opportunity for renewable - esp. PV technology	
	2008	**(F): polysilicon price drop. (I)Key for margin is to manage material cost and lower manufacturing cost**	**(F):polysilicon cost drop (I) industry supply chain adjustment , and PV would achieve grid parity earlier.**	**(F): polysilicon cost drop and over supply (I)may not yet achieve the lowest price . Industry transition**
	2009	(F) improve cell quality. (I) efficiency rate to differentiate competitors during industry downturn.		(F:) improve cell quality and **develop PV system. (I)** efficiency rate and **total solution to** differentiae competitors
	2010	(F) industry growth - I capacity expansion. **(I)Capacity expansion and evaluating different technologies.**	(F): industry growth. (I) Capacity expansion and improve efficiency rates and manufacturing process.	**(F):growth but not as fast as peers (I): major cause - polysilicon contract. Develop thin film technology**
	2011	(F): technology uncertainty - **different technologies & changing margin in value chain. (I)product competitiveness**/quality and evaluate different technologies	(F) supply over demand, dropping ASP, **(I) industry dramatic change.**	(F) over -supply and competition ;(I) fast dropping ASP and **unutilized production capacity**
Responding strategies	2003-2006	cell efficiency&capacity, new products of measuring equipments and PV system	N/A	N/A
	2007	plans for developing polysilicon crystal growth technology and BIPV system	capacity expansion & supply chain management	Develop self- owned c-Si technology platform (incl. manufacturing line)
	2008	Capacity expansion, develop **upstream polysilicon wafer technology; PV system & inverter as mid - long term strategy**	**Cost control and cash flow management;** improve cell efficiencies; **strategic alliance (supply chain).**	**Develop self-owed c-Si technologies; "not too aggressive expansion" ; develop global customers (leverage parent company's current channel).**
	2009	Differentiate product quality. **Upstream integration. Strategy alliance with TSMC** (semiconductor firm)	Improve cell efficiencies, yield rates and manufacturing process. **Speed up capacity expansion** (240MW-800MW)	Self-owned technology strategy. **Develop PV system** business
	2010	Capacity expansion, Vertical integration -upstream polysilicon wafer and **enter module assembly business**	Continue focused R&D strategy and capacity expansion	Continue self-owned technologies. **Thin film with IBM.** Capacity expansion, **module and system businesses**
	2011	Cost & technologies. Operation management , reach end customers as mid-long term strategy	Cost & technologies. Capacity utilization - increase installed capacity and cost competitiveness	Cost & technologies. Develop emerging markets

Source: Three firms' LTS 2003-2011, complied by the author.

General trend of LTS

LTS 2003-2007

During the period of 2003-2007, the three firms' LTS similarly show the optimism towards PV market growth driven by environmental and incentive policies. In 2007, polysilicon shortage amid strong demand was the three firms' attention focus.

LTS 2008-2009

The period of 2008-2009 marked the years of the global financial crises. Three firms obviously attributed the gloomy economic situation and policy uncertainty (particularly Spanish incentive scheme change) as the main reason for the first industry downturn. In contrast to the concern of rising silicon cost in 2007, in 2008-2009, the attention shifted to the over-supply issue resulting from pricing pressure (plummeting silicon price) and growing competition in the industry.

LTS 2010-2011

The period of 2010-2011 marked the two contrasting years of the industry boom and bust. The three firms' LTS in 2010 expressed similar optimism towards strong demand growth driven by the wide implementation of incentive policies. All three firms recorded rapid sales and profitability growth in 2010. Then in 2011, when the PV industry faced the second industry downturn, there was a dramatic change of mode in three firms' LTS in 2011. Although these firms may have slightly different perspectives about policy uncertainty, changes in incentive policies were not the only attention: these firms similarly recognized the challenge of worsening over-supply resulting from capacity competition and falling ASP (Average Selling Price) in the industry. The issue of how to achieve price competitiveness and cost reduction was

apparently the focus of three firms' LTS in 2011.

Selective attention – environmental uncertainty

While there are similarities regarding attention focus towards policy and technology uncertainty, the three firms' LTS also show differences with respect to interpreting the effect of environmental uncertainty. Firstly, in 2007, *Solar one* was the only one showing the early awareness of increasing industry players and competition[59]. Secondly, in 2008-2009, while *Solar one* and *Greenchild* showed a conservative attitude towards the pace of market growth, *FabPV* expressed a different view: the firm stressed the opportunity of fast growing demand derived from lower PV cell/module price module, on the grounds that PV technology would achieve grid parity sooner than expected. Further, the firms' LTS in 2008 indicate different perceived effect of policy uncertainty on the firms: while *FabPV* stressed the growing market size, *Solar one* was more concerned about the shrinking gross margin and *Greenchild* was the first one hinting the PV industry structural change in LTS.

The first difference in three firms' LTS in 2010 is the attention towards other PV technologies. While *Solar one* and *Greenchild* mentioned about the potential of alternative and emerging technologies in the PV industry, there was no messages about technologies other than c-Si cells in *FabPV*'s LTS. The second difference in three firm's LTS in 2011 is the attention towards industry change. Both *Solar one* and *FabPV* pointed out the structural change in the PV industry supply chain. But the two firms have different expression about the change: while *Solar one* emphasised the

[59] Another reason could be that *FabPV* and *Greenchild* were just officially entering the PV industry in 2007.

technology uncertainty associated with development of emerging technologies and value proposition, *FabPV's* attention focused on the structural adjustment of the supply chain. Although *Greenchild* firstly pointed out the sign of industry change in 2008 and the opportunity of emerging PV technologies in 2010, yet the firm did not address these messages in 2011. One of the attention focuses in the firm's LTS was the recognition of polysilicon contract issue leading to the firm's losses in 2011.

Selective attention – responding strategies

The three firms' LTS in 2008 illustrate the different strategy emphases in responding to the challenges of the first industry downturn. In fact, the indications of their different direction in responding strategies can already be traced from their LTS in 2007. *Solar one* stressed the firm's capacity in upward vertical integration (polysilicon wafer) and downstream PV system. *Fab PV* emphasized capacity expansion and the firm's competencies in cost control and operational management. *Greenchild* expressed the view that the firm would continue to pursue self-developed technology platform[60] and "not too aggressive" capacity expansion. Then in 2009, when the first signs of recovery were sighted after the easing of the financial crisis, the three firms still appeared to follow their same responding strategies since 2007. *Solar one* stressed the firm's *vertical integration* in both upward polysilicon wafer and downward module assembly. *FabPV* emphasized the firm's *focused cell manufacturing***.** *Greenchild* continued to highlight the importance of *self-developed technology* platform.

[60] It emphasises the total technology solution including manufacturing line (most PV cell firms purchase turn-key solution) on the c-Si platform.

Basically, the three firms responding strategies in 2010-2011 followed the same themes as those in 2007-2009. Although in 2010, the similar focus among the three firms was *capacity expansion*, which appears to be a reasonable action in the anticipation of rapid demand growth in 2010. While both *Solar one* and *Greenchild* stressed the firms' entry in PV module business in 2010, *FabPV* still focused on cell production. In responding to the industry downturn in 2011, apart from the central messages of cost reduction and technology improvement (c-Si technology), there were slight differences in three firms' LTS in 2011. While *FabPV* continued the focus of cost competitiveness, *Solar one* addressed the importance of reaching end-customers and *Greenchild* indicated the firm's efforts in developing emerging markets.

The relevance of selective attention to the firms' capability investment decisions

In investigating the relevance of selective attention to firms' investment decisions, the analysis is to find whether there is evidence linking these firms' selective attention to their capability investment pattern. Firstly, for the comparison of messages inside the firms' LTS, it draws on the connections between attention towards environmental uncertainties and responding strategies. Secondly, the LTS messages of these firms' responding strategies are cross-examined with their capability investment patterns.

Cases illustrating the linkage between firms' attention towards the environment and responding strategies

From the evidence of LTS, there are two cases illustrating the relevance between firms' attention towards the environment and their responding strategies. The first

case is that *FabPV* is the only firm held more optimistic view towards market demand growth during the period 2008-2009, when the industry experienced the first recession. The difference of attention in interpreting the effect of policy uncertainty was indeed reflected in *FabPV*'s announcement of capacity expansion strategies earlier than the others in 2008-2009.

The second case is that *Greenchild* is the only firm expressing the view of industry transition earlier in 2008, and different from the other two firms, *Greenchild* did announce investments of emerging PV technologies and PV system in the firm's LTS in 2010. Although there was two-year time lag, *Greenchild*'s responding strategies in 2010 could be reasonably traced from the firm's selective attention back in 2008.

Linking responding strategies to capability investment actions – the three firms' distinct patterns

However, a more important finding from the evidence of LTS is that these firms seem to follow similar responding strategies despite the change of attention towards the environmental uncertainty in different time period. To understand each firm's distinct pattern in different period of time, the evidence of LTS is further examined with capability investment pattern.

FabPV is the case illustrating the *consistent* pattern of the firm's attention towards environment, responding strategies and capability investments. Basically, the firm pursues the similar focused c-Si cell manufacturing strategy and there are no messages of developing alternative PV technologies, vertical integration or PV system in the firm's LTS.

Greenchild is the case demonstrating the *inconsistent* pattern in 2011. This firm is the only one with the evidence of new capabilities investments in 2010-2011. But the firm's LTS messages on attention towards the environment and responding strategies were not much different from those of the other two firms. *Greenchild*'s new capability investments of downstream PV system, the initiative of overseas PV system integration business was not mentioned in the firm's LTS in 2011; although this investment project was listed in the firm's board meeting notes and financial statements in the Annual Report of 2011. Moreover, despite with its large funding and project scale, *Greenchild*'s five- year MOEA project of CIGS thin- film technology was not mentioned in the firm's LTS in 2011, either. These missing statements may imply the fact that the initiatives of developing new capabilities were not necessarily considered by the firm as key strategies in coping with environmental uncertainties during this time period.

Solar one is the case showing that capability investment decisions may not necessarily be observed from the firm's attention toward the environment during different time periods. While most of *Solar one*'s LTS messages can be linked to the firm's vertical integration investments, the first noticeable gap is the attention towards PV technologies. In fact, *Solar one's* LTS in 2010 and 2011 clearly pointed out the potential of alterative and emerging technologies, but the firm did not invest in technologies other than c-Si platform. The second gap is that although *Solar one's* LTS in 2011 emphasized the awareness of industry structural and changing proposition change towards end customers, there was no evidence of increasing new investments in downstream PV system. On the contrary, there was a sign of contracting investments in the firm's system business line.

Summary

The attention-based view suggests that firms selectively perceive the environment: firms may "selectively focus" on particular issues while ignore others. The basic assumption is that firms' selective attention may affect their strategic choices (Cho & Hambrick, 2006; Ocasio, 1997). The findings from analysis of LTS show that there are evidences of selective attention among these firms: while there are traces of variation with respect to how these firm notice and interpreting the effect of environmental uncertainties in different period of time, the indications of variation in the firms' responding strategies are evident since 2007. However, the pattern of selective attention may not sufficiently explain the firms' heterogeneous pattern of capability investments.

5.2 Factors influencing selective attention

In examining to what extent firm characteristics influence the pattern of selective attention in the organization, Section 5.2 investigates two factors: firm resources and ownership.

The influence of firm resources

The "attention-based view" suggests that firms' resources influence how they notice and interpret the relevant issues in the environment[61] (Cho & Hambrick, 2006; Ocasio, 1997). Here the analysis of firm resources comparison is operationalized based on the competitiveness measurement in the PV industry. Four categories of critical resources in the PV industry are identified: scalable and differentiated technologies, operational excellence, access to markets/customers, and financing strength **(Table 5.2).**

Table 5.2 Three firms' resources comparison

[61] The resources and capabilities view (RBV) literature suggests that the firms' possession of resources and capabilities can be sources of heterogeneity in explaining firms' decision behaviours. Different from RBV, the attention based view emphasises that firms' attention is "shaped, but not fully determined, by existing organizational resources"(Ocasio 1997: 198).

Capabilities for the PV industry	Measurement	*Solar One*	*Greenchild*	FabPV
Scalable and differentiated technologies	Scale/capacity (cell) 2010[*1]	1.5GW	600MW	1.3GW
	Conversion Efficiency (c-Si cells)	Mono: 18.6%; Multi:17.4%	Mono: 19; Multi:18	Mono: 19%; Multi:18%
	Patents (US Granted)[*2]	1(supporting device/equipment)	1 (solar cell, module)	N/A
	Patents (US , EU, China application)[*3]	4 US, 1 EP, 5 CN	3 EP	4 US, 2 EP, 13 CN
	Patents (TWN)[*3]	8 TW	2 TW	19 TW
Operational excellence	Supplier relationship	key polysilicon procurement management	key polysilicon procurement management	key polysilicon procurement management
	Supply chain streamlining (vertical intogration)	Acquire a polysilicon firm and 2 module firms; wafer 500MW, module 100MW	Module product line (32% of current sales)	Own a module company, module business. Module : 50MW
Access to market/customers	Downstream system integration	Inverter (1% Sales); system integration/EPC (1% Sales)	Parent company- leading Inverter manufacturer; EPC operation in US and India subsidiaries (currently loss)	Plan to set up new EPC firm in 2012
	Customer knowledge/offerings	Extend EPC; leverage brand name and established customer base/connection	Leverage parent company's global market base/connection	Partnership to acquire an US power plant operation
	Sales (Global Market) structure (2011)	EU 36.07%, US 30.82%, Asia 21.44%, Domestic (TW) 11.39%, others 0.28%	EU 55.86%, Asia 11.85%, US17.65%, Domestic (TW) 4.25%, others 10.39%	EU 22.38%, Asia 35.96%, US 11.96%, Domestic (TW) 12.52%; others 17.18%
Financing strength (cost of financing)	Financial structure (2011)	Debt/Assets ratio = 0.44; Deb/Equity ratio = 0.77	Debt/Assets ratio=0.48; Debt/Equity ratio= 0.92	Debt/Assets ratio= 0.34; Debt/Equity ratio =0.51
	Cash flow (2011)	Operating cash flow ratio = -3.9%	Operating cash flow ratio = -47.8%	Operating cash flow ratio = - 11.6%
	Market type	Taiwan OTC listed	Taiwan Stock Exchange (TSE) listed	Taiwan Stock Exchange TSE) listed
	Main owners' support	Main owner -business group (20%)	Parent company- business group (60% share)	VCs and institution investors

**1: ECJHC PV report 2011; *2: Patent Lens ; *3: Espacenet* — *Source: firms' annual reports, business news; and compiled by the author.*

Source: data compiled by the author

Scalable and differentiated technologies

There are three measurements in this category including the firms' (1) current production scales, (2) progress of technology developments and (3) patenting activities[62].

Firstly (with the exception of *Greenchild*), two of the firms – *Solar one* and *FabPV* – have competitive production scales that rank highly worldwide. Secondly, the three firms have made commensurate technological progress on the c-Si platform in terms of c-Si cell efficiencies (Lin & Hsu, 2011) and new product releases over the past few years (Appendix 5-2). Thirdly, there are no significant differences in terms of granted patents[63] as well as the US and EP patent application process[64]. The vast majority of

[62] Although patents may not necessarily be the critical entry barrier in the PV industry, but may still represent technological resources to a certain degree.

[63] *Greenchild* has one solar cell/module patent, *Solar one* has one granted US patent (not on solar cells but on related equipment), and *FabPV* has no granted patents as of yet.

the three firms' patents are consistently categorized under H01 L31 and H01 L21, the two most prevailing IPCs for solar PV cells and module technologies. Both the indicators of new product release and patenting information suggest that the three firms' current efforts and developed technologies are not diversified, and that their focus of "differentiated technologies" still lies in the development of next generation c-Si cells and the respective manufacturing process. Overall, in the category of *Scalable and differentiated technologies,* apart from the advantage of production scale possessed by *Solar one* and *FabPV,* there is no significant gap in technological resources between the three firms.

Operational excellence

In this category, two measurements including the firms' supplier relationships (particularly the supply management of polysilicon) and the streamlining of the supply chain (particularly vertical integration in PV cell and module manufacturing) are evaluated. Firstly, all three firms have to rely on securing key procurement contracts (during the polysilicon shortage in the early years), or manage flexibility to avoid losses from price fluctuation (in recent years). *Solar one* appears to have more assets in terms of polysilicon wafer production, yet such a lead may not be significant – *Solar one* only produced around 500MW wafers, while first-tier Chinese PV firms' wafer production (as suppliers to most Taiwanese PV cell firms) ranged from 1000MW to 6500MW. On the other hand, *Greenchild* seemed to suffer badly from their polysilicon supplier contract, as the firm committed to a much higher price

[64] *FabPV* seems to be more aggressive in filing patents in China and Taiwan. However, the firm's CFO admitted that there may be only 1-2 patents that are critical to the firm, and that the firm's patenting activity may be an indication of image management. Similar comments on the potential technological value of these patents owned by *FabPV* were confirmed by the ITRI Solar division's deputy director.

before the sharp decrease in polyslicon costs. With this respect, *Greenchild* lags behind the other two firms in terms of supplier management.

Secondly, although *Solar one* led the way in vertical integration, such advantage only lasted for a short period of time: the firm's lead in module production has not necessarily been an advantage after the severe price drop in late 2011, as it may add to the cost (material and inventory) burden and further squeeze the composite margin. Accordingly, there is no significant gap in supply chain streamlining of PV cell and module manufacturing between the three firms.

Access to markets/customers

There are two measurements in the category including the degree of global market reach and the development of downstream business. Firstly, all three firms have already adjusted the previously EU-dominated market base to a more globally-distributed market structure by 2011, although *Greenchild* seems to be a little behind, with the EU share at over 55% in this case. Secondly, *Solar one* is the only firm that has developed both the PV system (including the PV inverter) and system integration for years. Yet the firm's EPC business has been limited in the domestic market since its development in 2003. Overall, there is again no significant resources gap among the three firms in the category of "access to markets/customers".

Financing strength

This category of resources is critical for PV firms' business operations, not only because the PV industry is capital-intensive (in terms of the need for purchasing

equipment and materials), but also because this resources may sustain investment activity during the credit crunch. The firms' financing strengths in terms of their basic financial structures and fund raising abilities are evaluated. While debt/equity ratios increased substantially at *Solar one* and *Greenchild* from 2010-2011, *FabPV* had a relatively stable debt structure. As for the operating cash flow, *Solar one* and *FabPV* seemed to be better-set to cope with the liquidity issue, yet it was *Greenchild* that had the strongest back-up from its owner – a large electronics company. Overall, judging from these indicators, there is again no significant gap in financing strength among the three firms. This fact also corresponds with the interviews: senior managers in the three c-Si firms expressed the same view, that their firms had no funding pressure regarding investment activities.

To what extent resources gaps explain selective attention?

The first noticeable gap among the three firms is that *Solar one*'s *vertical integration* (upstream and downstream) has been ahead of that of *FabPV* and *Greenchild*. Specifically, *Solar one* may have a certain lead in terms of the early entry into downstream PV system technology and experience. The influence of resources and experience in downstream PV system since 2003 is evident in *Solar one*'s attention towards the environment, particularly during 2010-2011, when the industry experienced dramatic structural change. However, *Solar one* did not capitalized this early advantage in the firm's responding strategies but pursued the same focused c-Si strategy similar to *FabPV* in 2010 and 2011.

The second noticeable resources gap among the three firms lies in the level of *production capacity* in which both *Solar one* and *FabPV* have substantial lead over

Greenchild. *FabPV*'s advantage in c-Si cell product scale appears to explain the firm's focused attention on c-Si platform and somehow pay less attention to the development of other emerging PV technologies. But *Solar one*, the firm with the commensurate c-Si production scale still shows the attention on the potential of alternative and emerging PV technologies. With respect to *Greenchild*, the firm's smaller production scale was not necessarily the rationale influencing the attention and responding strategies towards developing emerging PV technologies during 2010-2011. In fact, *Greenchild* has also been pursuing focused c-Si technology strategy since the firm's inception. The key message of "self-developed technology" in the firm's LTS from 2007-2011 refers to c-Si technology platform. *Greenchild* announced the speeding up of capacity expansion in 2010 and 2011, but the timing appeared to be late slow as the over-supply issue worsened during 2011[65].

Owner's influence

Next, from the three firms' profile, the difference in ownership type and structure is another noticeable firm attribute. It is reasonable to assume that the characteristics of the firms' owners may reflect the firm's high-level management structure and strategic directions (Baysinger, Kosnik, & Turk, 1991; Hoskisson, Hitt, Johnson, & Grossman, 2002; Zahra, 1996).[66] Therefore, here the factor of firm ownership is treated as another firm-level characteristic representing the aspect of organizational structural rule that may influence firms' attention towards the environment and responding

[65] In 2009, *Greenchild's* capacity was 192MW, only around 50MW less than *FabPV*'s 240MW. In 2010, *FabPV*'s capacity expanded to 800MW while *Greenchild's* capacity only reached 400MW. In fact, *Greenchild's* R&D Head admitted that compared to *FabPV*, the firm has been too conservative in business practices such as pricing and capacity utilization strategy during the past few years.

[66] Empirical studies on ownership suggest certain ownership structural factors such as ownership and shareholder types in predicting firms' attention focus and investment orientations.

strategies(Ocasio, 1997).

Looking into the three firms' ownership structure, they actually share similar traits, particularly ownership concentration and business group ownership. Thus here the comparison focuses on examining the characteristics of the three firms' owners and their influences on firms' selective attention **(Table 5.3)**.

Table 5.3 Three firms' ownership

	Solar one	*Greenchild*	*FabPV*
Firm establishment date	1981 (Entry SolarPV cell business in 2000)	2004	2005
IPO date	2003 (Over-the-counter) listed	2007 (Emerging stock); 2012 listed	2009 listed
Business group ownership	**No, From 2003- 2009** : individuals - founder and original owners (around 37%, with the founder's share 16.7%)	**Yes.** Business group- Parent company (electronic company). Before 2007 : 78%; after 2007: 59%	**Yes, Before 2009**: Business group (DRAM - electronic company)(32.64%);
	Yes, After 2010 : Business group - semiconductor company - the largest shareholder(20%)		**No, After 2009**: main shareholders- 3 VC (4.3%); 6 Institution investors (3.1%); Chairman 0.58%
Managerial ownership	**Yes**	Yes	Yes
	No, After 2010.		

Source: three firms' annual reports, complied by the author.

Solar one owner's influence: attention on c-Si process technologies

Unlike the other two c-Si firms, in which the ownership was backed by business groups during the founding period, *Solar one* was founded as an entrepreneurial firm, with the ownership dominated by original founders and angel investors. In 2010, a major shift of the firm's ownership structure was that *Solar one* introduced strategic partnership with a semiconductor company which became the firm's largest shareholder. The ownership of the semiconductor firm has brought in a new top management team (a new CEO and several new executives). According to remarks from *Solar one*'s CTO (who has been with the firm since 2000), the large semiconductor company is well regarded for its manufacturing R&D excellence, and

such influence is now evident on *Solar one*'s R&D, particularly in regard to the more systematic and performance-driven (e.g., targeting in cell efficiencies and yields) management. The messages of responding strategies from Solar one's LTS in 2009 also showed that the firm highlighted the role of improving operation management and process technologies through introducing the process know-how utilized in the semiconductor manufacturing process**.**

Greenchild owner's influence: attention on self-developed platform

Greenchild's owner has been characterised as a company interested in various technological innovation investments[67]. As a diversified venture of a large electronics company, *Greenchild* is considered to have been backed by the parent company's R&D resources. The firm's R&D Head expressed the view that *Greenchild* has been able to leverage the R&D pool from the parent company[68]. For example, *Greenchild*'s parent company invested in several research centres with universities, and these R&D sources could be shared among several company ventures. In addition, considering its relatively small size in comparison to *Solar one* and *FabPV*, *Greenchild* actually invested more in R&D expense (as a percentage of sales and as an absolute amount) than either of them (Appendix 5-3)**.** Further, while *Solar one*'s CTO admitted that the "Research" portion of the firm's R&D activities was quite small, *Greenchild*'s R&D Head revealed that the firm's "Research" accounted for around 30% of the R&D investment. The evidence of the firm's LTS from 2007- 2011 consistently delivers the message of the responding strategy of self-developed

[67] *Greenchild*'s parent company has been given an award for being the most innovative firm in Taiwan, based on the measures of new product development and its patent portfolio. Data sources are from *Greenchild's* parent company's annual reports, the comments from the third-party stakeholders and from various business news.

[68] *Greenchild*'s R&D Head indicated that this is the reason why the firm could manage to develop different product lines (PV cell and module) and alternative PV technologies, given the firm's relative small size compared to *Solar one* and *FabPV*.

technology platform[69]

FabPV – no evident owner's influence

While the cases of *Solar one* and *Greenchild* suggest the strong influence of a single business group owner on the firms' selective attention, the case of *FabPV* did not show the evident firm owner's influence. *FabPV* had business group ownership when the firm was founded. However, unlike *Greenchild*, the ownership was not in the form of a diversified company venture, but rather in the form of a financial investment. In fact the main shareholder, a DRAM company, sold most of its share as soon as *FabPV* was IPO-listed in 2009. Since then, *FabPV* has had a more distributed ownership structure composed of of several VCs and various institutional investors. At first sight, *FabPV*'s previous business group owner's interest in profiting from IPO seems to explain the firm attention focus on profitability, cost control and cash flow management highlighted in *FabPV*'s LTS in 2008. Yet after the exit of the main business group owner, the evidence from LTS showed no major change in the firm's responding strategies.

To what extent owners' traits explain selective attention?

The cases of *Solar one* and *Greenchild* suggest that their owners' traits such as *industry experience* or *research propensity* may influence the firms' selective attention in responding strategies. From a general perspective, the differences in the two firm owners' industry experience appear to lead the prediction of differentiated attention towards exploitation (focused c-Si platform) or exploration (developing other

[69] *Greenchild* developed its manufacturing turn-key solution and owned a US granted PV module patent.

technologies): the semiconductor company (*Solar one*'s owner) is well- known for the process technologies, which corresponds to the propensity of improving c-Si manufacturing process; the electronic company (*Greenchild*'s owner) is famous for developing of electronic devices and systems, which can be associated with the inclination of exploring various technologies. However, the finding suggests that, while owners' industry experience may explain the differences, it may not be sufficient to predict the orientation towards exploitation or exploration. In the case of *Solar one*, the semiconductor owner actually invested in a CIGS venture (an evidence of developing alternative and emerging PV technologies) in 2010. Therefore, the reason why *Solar one* didn't invest in exploration for other PV technologies may lie in that the firms' technology direction would need to be orchestrated with the semiconductor owner's solar PV development strategy[70].

Summary

Drawing on the attention-based view, the analysis of Section 5.2 focuses on examining to what extent firm-level characteristics - firm resources and ownership explain variation in selective attention (Ocasio, 1997). Firstly, *t*he three firms' resources comparison shows that there are two noticeable differences in production scale and degree of vertical integration. The analysis shows that both differences may not sufficiently explain the firms' selective attention in responding strategies.

Secondly, the firm ownership appears to be a more explanatory factor compared to firm resources in demonstrating firms' variation in selective attention. However, the

[70] *Solar one*'s CTO implied that while the firm would be interested in emerging PV technologies such as CIGS, the firm owner had already invested in CIGS. Similar comments were confirmed by the firm's deputy CFO.

analysis suggests that, the prediction of the influence of specific ownership characteristics (such as firm ownership type or owners' industry experience) on firms' selective attention can be subject to other moderating factor (such as owners' goal for investment). The prediction can be varied in explaining firms' distinct pattern in different time period**.**

5.3 Towards a causal combination view

Section 5.3 starts with examining the influence of CEO's experience on their selective attention and firms' propensity in capability investments. Then Section 5.3 discusses how the causal combination view illustrates the analysis of firms' capability investment patterns.

CEO's selective attention

The investigation of CEO' influence on firms' attention focus draws from the classic concept of selective attention that individual decision makers' knowledge, value and experience may affect how they attend to the environment and interpret the relevant issues. The central role of CEO in firms' strategic decisions has been emphasised s in Top management Team (TMT) and managerial capability studies (Finkelstein et al., 2009; Teece, 2012). Specifically, founders' or *CEO's prior experience* has been considered as an important indicator in explaining how firms in the same industry are differentiated in terms of entrepreneurial focus (Cho & Hambrick, 2006), investment orientations (Helfat & Lieberman, 2002), or how they are constrained with investment choices (Fern, Cardinal, & O'Neill, 2011).

Here the analysis focuses on the comparison of CEO's experience, which is cross examined with their remarks (collated from their interviews on the business news) and these firms' investment patterns.

CEO's experience in influencing market entry and exploratory investments –Solar one

In addition to the different pattern in capability investments **(Table 5.4)**, a major difference among the three c-Si firms is the *timing of their entry* into the PV market. *Solar one* had a relatively early entry in 2000, but *Greenchild* and *FabPV* entered the market a few years later in around 2006, at the time when the solar PV market started to take off. *Solar one'*s vision of early entry into the PV industry was formed in the match between an entrepreneur's attempt to transform the small electronics firm and a scientist's observation of market opportunity. According to *Solar one*'s co-founder of the PV business (formerly a scientist working at the National Renewable Energy Lab in the US), back in 1997 he observed that the manufacturing technology of PV cells was close to the brink to mass production; while the German and Japanese Governments showed initial signs of providing generous government support, there were few players at the time (CW, 2005)[71]. This idea was supported by his college friend, *Solar one*'s founder, who was seeking to create new business for his small firm[72]. The founding CEO's entrepreneurial trait of developing new businesses may explain the firm's exploration investments in the early years: *Solar one*'s investments in developing new capabilities were at their most active and diversified during his tenure up until 2007.

CEO' functional experience in influencing investment direction – FabPV and Greenchild

[71] This inspiration about of the PV industry is derived from the experience of working with PV technology at NREL: the co-founder described that the connection to some of the firm's important customers was built when he worked as the UN (United Nation)'s technology consultant to several governments' solar PV projects.

[72] *Solar one* started as a small entrepreneurial firm designing and manufacturing testing equipment in 1981.

While the unique experiences of *Solar one*'s two founders illustrates the firm's early entry into the market and the diversified investment pattern, the prior working experience of *Greenchild*'s and *FabPV*'s CEO may also link to the two firms' different investment directions, even considering their very similar market entry times. Unlike *Solar one*'s co-founder, the two CEOs had no prior experience in PV technologies, yet the clear distinction between a scientific background and management discipline shows in how they viewed PV market opportunity and their firm's development direction.

Greenchild's CEO served as Chief Technology Officer at the firm's parent company[73]. Before that he was chief scientist at Polaroid in the US. In a press interview in 2010, *Greenchild*'s Chairman/CEO expressed the view that in addition to current cell technologies and some new research projects (such as CZTS thin film), the firm may be interested in exploring the related areas of smart grid and storage technologies, particularly because solar PV is an intermittent energy source, and "smart grid can manage and adjust the misused electricity, which is the key to the future intelligent lifestyle" (Chiu, 2010). It is not surprising that the CEO initiated investment projects in emerging PV technologies and the downstream solar PV system.

FabPV's CEO served as Chief Information Officer in a large semiconductor company. As a senior executive in the semiconductor company, the Chairman/CEO had been well known for developing the company's production and supply chain solution. In a press interview in 2010, the Chairman/CEO stated that "PV is expected to reach grid parity in 2011", and that "cost, quality and operational excellence will be the key

[73] *Greenchild*'s founding CEO was appointed by the parent company in 2007, around two years after the firm was established.

competitive advantage in the PV industry." (Huang, 2010). It is evident that the CEO has had the clear goal of being a professional c-Si cell manufacturer since founding the firm, which is consistent with the firm's investment pattern of dedicating resources to c-Si cell technology.

The observation of how the founding CEO's prior experience differently influences the two firms' investment directions is also supported by the VC's (the investors of both firms) comments: "apart from the two firms' financial performance indicators, *Greenchild* is influenced by the Chairman/CEO's passion for technology, who personally owns numerous worldwide patents, although none of them are in the PV technologies", and "*FabPV*'s is inherited with the CEO's working style, who is the expert in the field of supply chain management".

Conditions for predicting the influence of CEO experience

In the context of the three Taiwanese PV firms, the finding suggests that CEO's prior experience may influence their firms' selective attention and serve as an indicator to discriminating firms' capability investment directions. However, the perspective of "priming effect"[74] in interpreting successful experience suggests that, it appears to be easier to attribute the CEO effect based on the historical data, because it is such an obvious target to associate with the firm's strategic orientation; particularly if the targeted firm analysis was a success story. The influence of CEO experience could be overemphasised because of the coincidence of timing and luck (March, 2010). For example, in the case of *Solar one*, although CEO's related PV industry experience

[74] There is a specific meaning defining the priming effect in behavioural decision theory: it refers to one of the anchoring biases; the influence of the target anchor in the judgment process.

appears to have helped the early detection of market entry timing, the CEO (the Scientist of NREL) revealed that he didn't expect the PV market to reach today's scale, and that it was "luck" to discover the opportunity in his "accessible working environment" and to develop the business at the right time (with the support from his friend's business).

Further, there are some conditions for the prediction of CEO's influence in the specific context of Taiwanese PV industry. Firstly, there is the similarity of seniority as an experienced professional in terms of both industry reputation and networks. These CEOs are characterized as being middle-aged entrepreneurs[75]. Most of them entered the PV business in their 50s, pursuing a new career path in the PV industry after retiring from firms (in large business groups) or research institutes. As the growing PV market has attracted a surge of investment funding for new entry firms (Bloomberg, 2010, 2011a; PIDA, 2011; Selya & Robert, 2010; WealthPress, 2005, 2009) in the past few years[76], the seniority of these CEOs indicates the importance of access to capital in the PV industry. Secondly, the condition to link their dominant influence with the firms' investment orientation is their structural position both as Chairmen and CEOs, implying the interest alignment of the ownership and the power concentration in the firms (**Table 5.4**)

Table 5.4 Comparison of three firms' CEO and capability investment pattern

[75]It seems to be common among Taiwanese PV firms: besides the three case firms, a similar case is found in the other two case firms and several other PV firms.

[76] In fact, apart from *Solar one*, the vast majority of the Taiwanese PV cell firms entered the market after 2005.

	Solar one			*Greenchild*	*FabPV*
	Founder/Founding CEO	CEO	CEO**	Founding CEO	Founder/Founding CEO
Tenure as CEO	2002-2007	2008-2009	2009-Current	2007-2011	2005-Current
Position at Board during CEO tenure	Chairman	Chairman*	NIL	Chairman***	Chairman
Education	BS in Physics	PhD in Physics	PhD in Material Science & Engineering	PhD in Polymer Engineering	PhD in Technology Management
Age (as of 2011)	60s	60s	60s	60s	60s
Prior working experience (before the firm)	Entrepreneur	Scientist at NREL	Executive at the owner's company (semiconductor)	Scientist at Polariod; CTO at the Parent (owner's) company	CIO at a semiconductor company
the Firm's new capability investments during CEO tenure	2002- 2005 : started PV system and Inverter business lines; 2007 : set up Energy IC design firm	NIL (but as c-founder of the firm's solar business lines started in 2002)	NIL	2010: CZTS thin-film and EPC busines; 2011: CIGS thin- film	NIL
** : served as Chairman/CEO 2008-2009; remains as*					
***: appointed by the largest shareholder (business*					
****: Resigned CEO (remains Chairman) in March*					

Source: the three firms' annual reports, business news and complied from the author.

Towards a causal combination view

The findings from Section 5.2 show that firm characteristics such as resources and ownership may have influences on firms' selective attention yet not sufficiently explain each firm's distinct pattern. In Section 5.3, the finding from CEO's selective attention suggests that, despite CEO's experience seems to be a more viable indicator explaining these firms' variation in investment direction, there are still certain conditions for predicting the influence of CEO's prior experience on firms' new capability investments in the specific context of Taiwanese PV industry.

From the perspective of seeking a contextual description of each firm's unique pattern, the findings from Chapter 5 are consistent with the "attention-based view" in which the basic claim that organizational factors "may shape but not necessarily determine"

selective attention is emphasised in explaining firms' decision behaviour.

However, for the purpose of constructing a more stylized analysis to explain the interaction effect of these organizational factors, here the framework of "causal combination view" is proposed: **Table 5.5** presents a simplified presentation of "truth table" (Ragin, 1994a, 2007) summarising the empirical investigations of the three c-Si firms. The emphasis is on comparing the similarities and differences of these factors to identify sources of variation. The element of "timing" is incorporated in the joint-assessment of causal factors.

Table 5.5 The comparison of three firms' causal combination pattern

Case firm	Resources				Owners' orientation in developing various technologies	CEO experience (propensity in exploration)	Selective attention - LTS Responding strategies (intention in developing new capabilities)						Investments in new capabilities	
	differentiated technologies	Scales & Operational excellence	Access to customers	Financing strength			pre 2007	2007	2008	2009	2010	2011	2003-2008	2010-2011
Solar one	0	1	1	1	0	1	0	1	1	0	0	0	1	0
FabPV	0	1	0	1	0*	0	N/A	0	0	0	0	0	0	0
Greenchild	0	0	0	1	1	1	N/A	0	0	1	1	0	0	1

** no evident owner's influence*

P.S: "1" stands for the presence of the investigated factor; and "0" stands for none.

Sources: the author

Firstly, from **Table 5.5**, there are some factors that can be identified as *irrelevant* in explaining firms' variation in capability investment pattern. These factors include *differentiated technologies* and *financing strength*. Then with respect to "*intention in developing new capabilities*" in selective attention, it shows that three firms' *LTS in 2011* can be irrelevant in explaining firms' variation.

Secondly, *Solar one* is a positive case showing the relevance between selective attention and investment in new capabilities in the period of 2007-2008. The causal combination includes the factors of *access to customers* and *CEO experience*. The resources factor of *access to customers* appears to be critical in differentiating attention focus, which is highly related to the value proposition in the PV industry, as discussed in Chapter 4.

Thirdly, *FabPV* is the negative case for new capability investments but a conforming case for the relevance between selective attention and investment pattern. The noticeable factor to differentiate *FabPV* from the two firms is *CEO experience*, which is also shared *in Solar one* and *Greenchild*'s causal combination. This finding indeed supports the statement that CEO experience can be a plausible indicator predicting firms' new capability investment pattern in the context of the three Taiwanese PV firms.

Finally, *Greenchild* is another positive case showing the relevance between selective attention and investment in new capabilities roughly in the period 2009-2011. The causal combination includes the factors of "*lacking scales and operational excellence*", *owners' orientation* and CEO experience. However, *Greenchild* is not necessarily a fully conforming case demonstrating the relevance between selective attention and new capability investments for two reasons. The first is that the evidence of selective attention only partially links to the timing of new capability investment (no evidence of selective attention in 2011 yet with evidence of new capability investments). The second is that there is a three-year time lag in connecting the factors of *owner's orientation* and *CEO experience* to the firm's investments in new capability development.

Summary

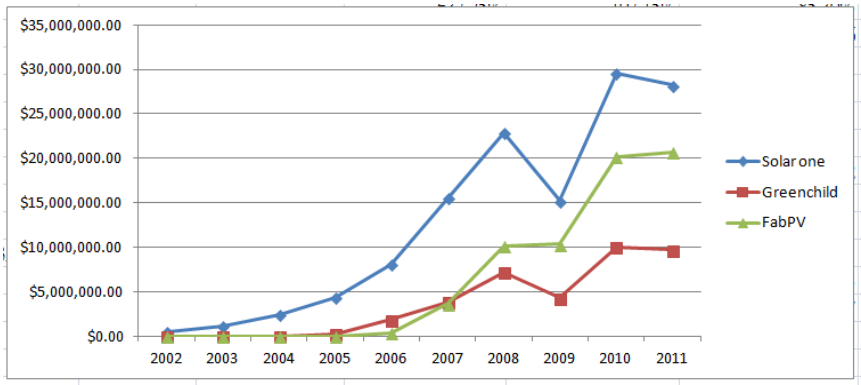
The finding from Section 5.3 shows that there is evidence of CEO selective attention among the three firms. While the analysis suggests that CEO's experience appears to be a more viable indicator than other firm-level factors (such as firm resources and ownership) in illustrating firms' variation in capability investment pattern, such prediction can be limited to certain conditions in the specific industry context.

In advancing the analysis of firm level selective attention and capability investment pattern, Section 5.3 further proposes that the framework of "casual combination view" may provide a more stylized analysis for explaining how the interaction effect of these organizational factors influences firms' distinct pattern.

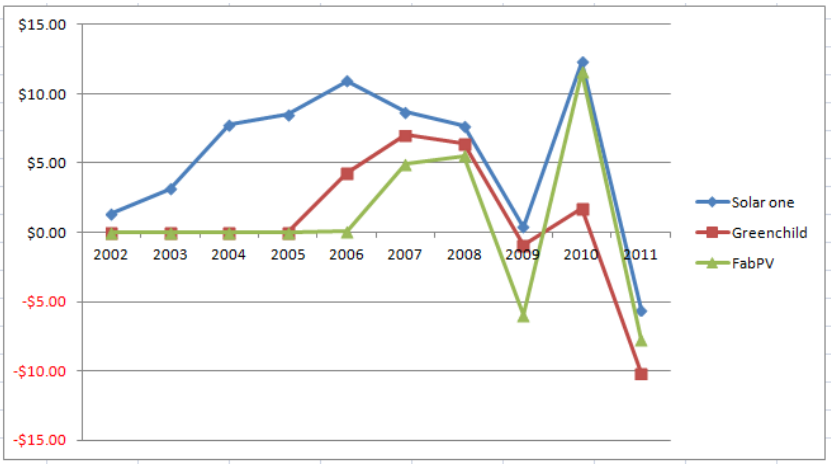
In answering the research questions "*What is the role of framing in the decision-making process for new capability investments, and what factors may influence the role of framing in such process?"* the findings from Chapter 5 show that there is evidence of firm–level selection attention and that the causal combination view reveals different influences of the firms' specific context in different time periods. However, the analysis suggests that such differentiated framing exists but does not sufficiently explain firms' decision pattern of capability investments.

<Appendix 5-1 Three firms' Sales and EPS Trend>

Three firms' Sales trends



Three firms' EPS trends



Source: firms' annual reports, compiled by the author.

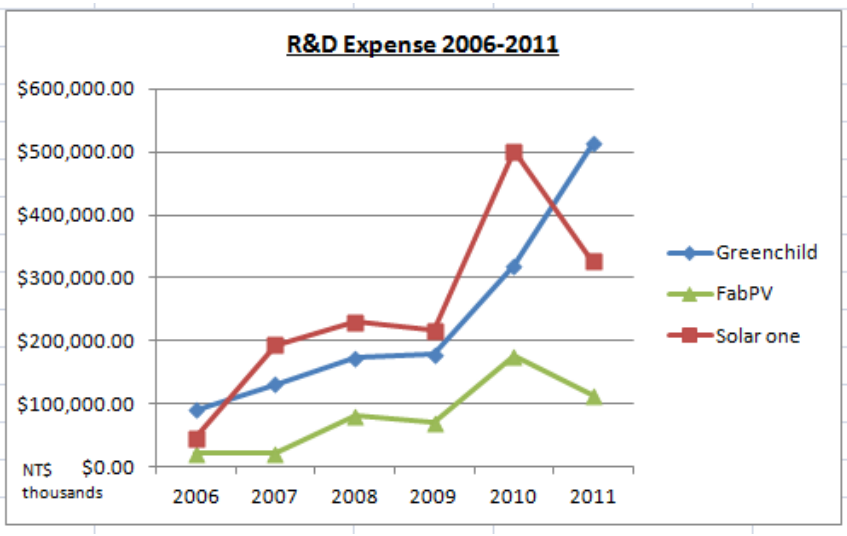
<Appendix 5-2 Three firms' new product releases>

	Solar one	*Greenchild*	*FabPV*
2009	New monocrystalline Si cell : "**X-CELL**" with 17.5% efficiency rate (production)	N/A	New monocrystalline Si cell: "**Perfect Cell**" with 17.8% efficiency rate; joint development with Chinese wafer firm's "Perfect Wafer"
2010	New module: "**IM60**" ; "**IM72** and"**XS60**"; "**XS72**"	New monocrystalline Si-cell: "**D6E**" &"**D6G**"with 19% efficiency rate; New multicrystalline cell: "**D6R**" &"**D6P**"with efficiency rate 17% and 18% ; New module.	New multicrystalline Si cell :"**Super 17**" with efficiency rate above 17%; New monocryatalline Si cell: "**Perfect 18**" with efficiency rate above 18%.
2011	New muticrystalline and monocrystalline cells: : "**LEO**" with efficiency rate 17.4% and 18.6%. **Inverter 5300U**	**CZTS thin film** technology with lab efficiency rate 10%, joint development with partners; New mono c-Si module: "**D6M265B3A**" ; New multi c-Si module: " **D6P240H3A**".	New monocrystalline Si cell: "**Black 19**" and "**Perfect 19**" with efficiency rate above 19%.

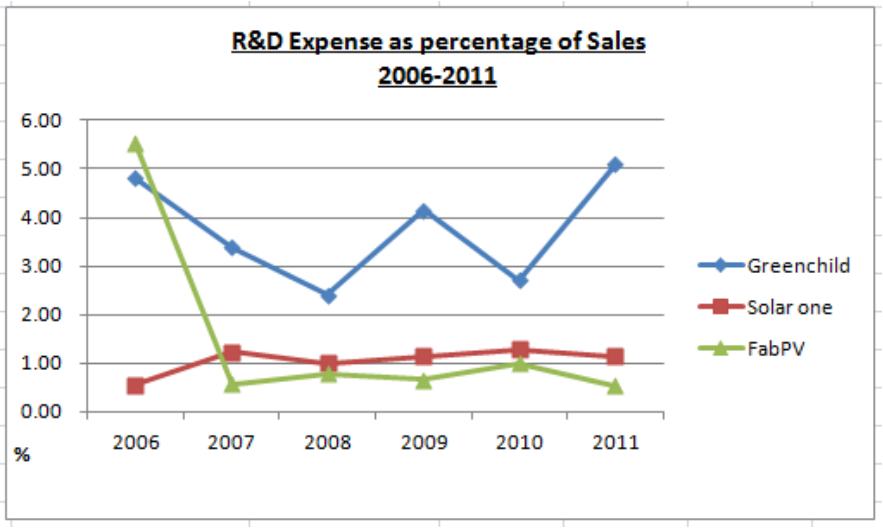
Source: the firms' annual reports and press releases, compiled by the author.

<Appendix 5-3 Three firms' R& D expense comparison>

Three firms' R&D Expenses 2006-2011



Three firms' R&D Expenses 2006-2011 (percentage of sales)



Source: firms' annual reports, compiled by the author.

Chapter 6

Selective Attention at the Senior Manager Level

Introduction

In addressing the research questions "*What is the role of framing in the decision-making process for new capability investment, and what factors may influence the role of framing in such process?"*Chapter 6 focuses on selective attention at the decision maker level with the empirical investigation of senior R&D and finance managers from the five Taiwanese solar PV firms.

As Chapter 6 employs an integrative view for the decision-maker level of analysis, the definition of framing in Chapter 6 incorporates both the organizational decision perspective of selective attention and behavioural decision perspective of heuristic judgement. This Chapter focuses on investigating factors that may influence selective attention at the senior manager level and examining how selective attention at senior manager level influences the judgment and decision process.

Section 6.1 starts with investigating the presence of selective attention which is examined by the patterns of opportunity recognition at senior manager level. There are three indicators for the investigation of opportunity recognition: responses to short-term market signals, evaluation of long-term market scenario and attention towards technology development.

Section 6.2 examines to what extent senior managers' selective attention is relevant to firms' decisions process for capability investments. Firstly, it analyzes senior managers' attitude towards competitors to illustrate why such selective attention may not necessarily be relevant to explain firms' decision patterns. Secondly, it examines senior managers' responses on the firms' search activities. The investigation of firms' search activities is employed as the measure of firms' propensity to explore and develop new capabilities. Section 6.2 discusses to what extent the firms' search patterns are influenced by senior managers' selective attention.

6.1 Selective attention in opportunity recognition

Extant studies use two different directions in evaluating selective attention at the senior manager level. Firstly, a number of studies from various industry sectors suggest that senior managers' functional roles and working experience influence their problem-framing and opportunity-recognition[77]. For example, in a study of 4 bankers and 4 entrepreneurs, the authors found that while entrepreneurs tended to focus more on controlling the "return" of the decision outcome, bankers tended to focus on controlling the "risk" involved in the decision problem (Sarasvathy et al., 1998). The study of 9 executives from the marketing service and life science industries found that individuals' prior knowledge may have significant influence in the cognitive process of opportunity recognition (Gregoire et al., 2009). In another study of 8 CFOs and VPs from the diversified food industry, the author found that these executives differed in their attention to business issues and the assessment of acquisition targets. Further, a similar line of reasoning is found among executives with the same functional role, which suggests that there is a "shared expertise" in corporate functional areas (Melone, 1994).

Secondly, other studies emphasise the organizational-level influence on senior mangers' perception and problem-framing in the decision process. For example, the study of 23 executives in a large manufacturing company found that executives' problem-recognition is associated with their departmental affiliation. The authors then propose that senior managers' selective attention is a learned response driven by the goals and motivations of their departments (Dearborn & Simon, 1958). Studies emphasizing the influence of the decision context suggest that senior managers'

[77] These studies employed the verbal protocol methodology.

attention focus and opportunity recognition is shaped by the organization's characteristics. For example, the study of 30 firms in the airline industry found that the attention towards regulatory change was influenced not only by the firm's TMT's experience but also by the incentive structure in the organization (Cho & Hambrick, 2006). In another study of firms in the telecommunications equipment industry, the authors found that CEOs' attention towards the emerging fibre-optic technology was influenced by the firm's propensities towards market entry time and the firms' capabilities (measured by their years of experience in that area) (Eggers & Kaplan, 2008; Kaplan, 2008a).

Here senior managers' selective attention is examined by opportunity recognition which is relevant to how senior managers perceived the environmental uncertainty in the decision –making process for new capability investments. There are three indicators for the investigation of opportunity recognition: responses to short-term market signals, evaluation of long-term market scenario and attention towards technology development. There are 8 senior managers – 4 senior R&D managers and 4 senior finance and business managers participating (individually) in the in-depth interviews. The analysis emphasises similarities and differences among senior managers and is cross –examined with their functional roles, professional experience and firm affiliation.

Responses to market signals

There are four categories of market signals[78]including *macroeconomic conditions, policy announcement, technology progress* and *PV industry/market indicators*.

[78] These signals are also reviewed by the industry experts before the interview.

Senior managers were asked to indicate the relative importance of these signals on their firms' new capability investments and describe the reasons, particularly for those signals identified as very important or unimportant **(Table 6.1).**

Table 6.1 Market signal analysis

Signals		Reported impact	Specific Comments on impact
Macro economic conditions	Prediction of economic outlook	*Solar one*'s **d. CFO; *Amorphous*' GM; *FabPV*'s CFO**	*Solar one*'s **d.CFO**: " We always incorporate the economic factors into our investment evaluation model."
			Amorphous' **GM**: "economics conditions may impact our new technology (innovation) projects- "under the condition of gloomy economic outlook, we might consider postponing new investments."
	Prediction of the oil prices		*FabPV*'s **CFO**: "sometimes the bad time may just be the good timing for investments in new technologies or business – as long as we have sufficient cash position during the recession."
			Solar one's **CTO**: "gloomy economic condition is expected; so it will not be a critical factor affecting our new technology projects."
			Amorphous' **R&D Head**:" economic conditions may impact our investment on current platform, but not on new technology project
Policy announcement	Enforcement of a new environmental		*Solar one*'**CTO)**: "policy change is expected: but environmental policy is towards the positive trend."
	Announcement of change on government		*Newsun*'s**CSO**: "policy patterns are varied in different regional (country) PV markets."
			Greenchild'**s R&D Head**: "although policy change may influence our business, it would not affect our investment in new technologies."
Technology progress	New technology progress/product release by industry leaders/competitors	**All**	*Solar one*'s **CTO**: "We will monitor competitors' progress; ...lab report has limited impact :the lead time from lab invention to commercialize is long (at least more than 6 months or much longer).
			Amorphous' **R&D Head**: "We would reference industry leaders' progress; ...the timing for new breakthrough is unpredictable
	Lab report from scientific/technological community on major breakthrough	*Greenchild*'**s R&D Head**	*Newsun*' **CSO**: "competitors' progress is more important than lab result- the lab report has been there for a decade, the key is production with stable quality."
			Greenchild's **R&D Head**: "industry leaders and competitors' product announcement and the lab reports are critical in assessing our investments."
			FabPV's **CFO**: " We need to evaluate the "market" for the technology and we will work with the winners".
Market indicators	Price cut by leading solar PV firms or competitors	*Solar one*'s **d. CFO; *Amorphous*' GM; *FabPV*'s CFO**	*Solar one*'s **d.CFO**: "the price trend is also an important factor to include in our ROI evaluation."
			Amorphous' **GM**: "market situation may affect our investment direction."
			Solar one's **CTO**: "price competition is expected."
			Greenchild's **R&D Head**: "Market price may indirectly impact cost issue of technology investment but not on our technological investment decisions.
	Announcement of new deployment project in terms of scale or applications	*Amorphous*'**R&D Head; *Newsun*'s VC BOD**	Newsun's VC BOD: " the trend of worldwide large scale PV project deployment is an indicator of the market outlook and applications."
			Amorphous' **R&D Head**: " the signal of more BPIV deployments is important to endorse our investment efforts."

Source: interviews and compiled by the author.

The influence of functional roles

Among the four categories of market signals, the noticeable difference in dividing two functional groups (R&D and finance) lies in how they viewed the impact of "predictions of economic outlook" and "industry competitors' price cuts" on their firms' new investment decisions: the three senior managers with finance/business[79] roles appeared to be more sensitive to the effect of policy and market uncertainty on investment decisions. These senior finance managers agreed that economic condition was one of the most critical factors influencing their firm's new investment decisions. On the other hand, senior R&D managers similarly described that the economic outlook would not affect their firm's decisions in terms of new technology investments, although they admitted that the economic situation might affect cost issues in their new investment projects.

The influence of prior working experience

While these senior finance managers expressed a similar attention direction towards the external environment, they reported different *action assessments* on the signals of economic impact. The differences can be traced from their working experience. *Solar one*'s deputy CFO said:"we always incorporate the economic factors into our investment evaluation model". Before attaining his position in *Solar one*, the deputy CFO worked as an analyst in an investment bank. *FabPV*'s CFO described that "sometimes the bad economic condition may just be the good timing for new

[79] There is no CFO (only an accounting manager) in *Amorphous*. The General Manager oversees the role of CFO (particularly in investment decisions).

investments – as long as we have a sufficient cash position during the recession". Prior to *FabPV,* the CFO had been CFO of several electronic firms and had a reputation for operating financial derivatives and hedging on the foreign exchange[80]. *Amorphous*' GM stated that "under the condition of a gloomy economic outlook, we might consider postponing new investments". The GM worked at the research institute and was not involved with finance or business functions before he gained his position at *Amorphous*. According to third-party interviewees (VC and MOEA), the small thin film firm has been under pressure during the industry downturn, and withdrew from its emerging stock listing market in 2011.

The influence of current working context

The influence of the individual's current working context shows in the response to project deployment announcement. Only *Newsun*'s VC BOD and *Amorphous*' R&D Head indicated that this signal would significantly impact on the firms' new investment decisions. The two senior managers' interpretations of this market signal are highly related to their specific experience in current working context: *Newsun*'s BOD has been in charge of his VC firm's solar PV investment projects for the past few years. In view of the recent industry downturn, signals of a worldwide large-scale PV deployment would be a critical factor in justifying his judgment about the potential of their investment projects. Similarly, *Amorphous*' R&D Head has been promoting the BIPV project in the firm; however the firm's GM recently had some doubts on the potential of this market segments. Thus positive news about BIPV deployment would help to endorse the R&D Head's position.

[80] According to the senior finance manager of another electronic company (informal interviewee, who has worked with *FabPV*'s CFO).

Finally, while senior R&D managers' functional roles certainly lead their attention direction towards technological progress, only *Greenchild*'s R&D Head indicated that the signal of a lab report was critical to the firm's investment decisions. The other senior R&D managers didn't consider the lab report to be a signal affecting their firms' decisions for the reason that it would involve a long lead-time from lab results through to mass production. Given the fact that at least two of the other three senior R&D managers at *Solar one* and *Amorphous* similarly possessed relevant PhD and research experience, *Greenchild*'s response may reflect the firm's relatively intensive research activities (around 30% of research in R&D) compared to the other two firms[81].

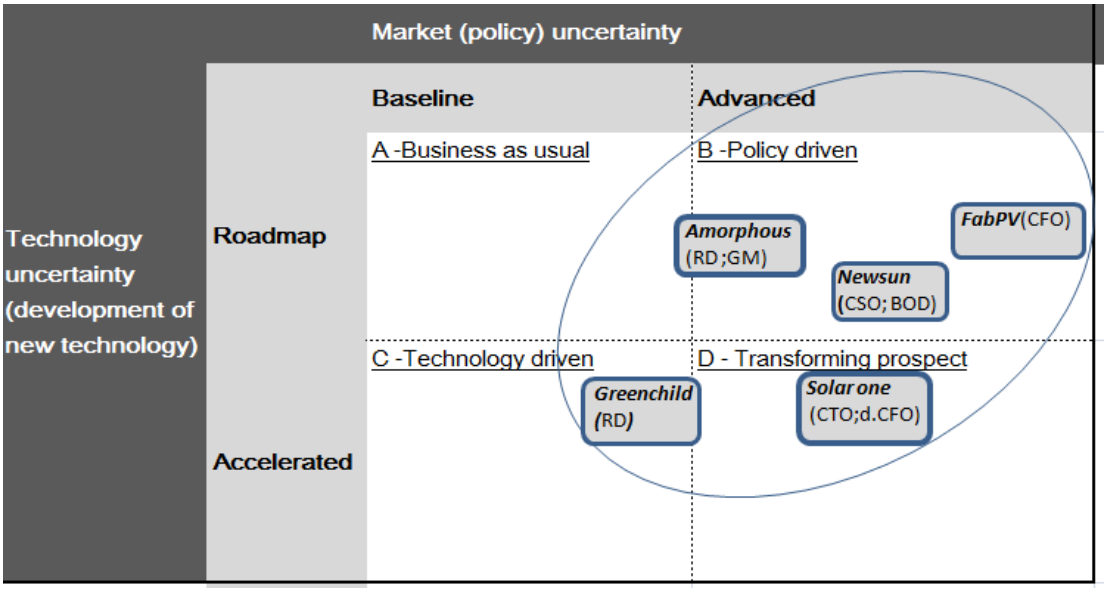
Market scenario

Among the four scenarios[82], senior managers were asked to provide ranking and explanations for the most probable scenario in the next five years **(Figure 6.1)**.

Fig 6.1 Scenario analysis

[81] *Greenchild'*s RD Head also recognized the fact that lab reports do not necessarily influence current market, but he still stressed its importance in influencing the firm's evaluation for new technology investments.

[82] These scenarios are reviewed by the industry experts before the interview.



Source: interviews and compiled by the author.

Under the general convergence trend towards the direction of policy driven scenario, the slight differences in the market scenario still show firm-specific patterns; particularly in the two contrasting cases of *Solar one* and *Amorphous*[83]. In separate interviews, *Solar one*'s CTO and Deputy CFO selected the same scenario – D (transforming prospect). Meanwhile, in separate interviews with *Amorphous'* R&D Head and GM, both senior managers selected the same scenario – B (policy driven) – despite the two senior managers' opposite views regarding the firm's BIPV development[84]. *Solar one*'s two senior managers were both optimistic about future developments in the PV industry and the opportunities for c-Si products. Yet *Amorphous'* R&D Head and GM both expressed a less optimistic view about market trends, and less certainty about the direction of thin film products. One contrasting fact about the two firms is that while *Solar one* is a worldwide top ten c-Si firm, *Amorphous* is a small thin film firm struggling to survive in the face of serious price

[83] Firm-specific patterns are also visible in *Newsun*. Only one senior manager from *Greenchild* and *FabPV* respectively participated in the scenario analysis.
[84] While the R&D Head considers BIPV to be a potential niche market for the firm, the GM thinks otherwise and is convinced that the volume-driven market is still the right strategy.

competition from c-Si firms. These senior managers' framing of future trends can be affected by the firm's current competitive status in the industry.

As for *Newsun*, despite the firm's current dedication to CIGS thin film technology, neither the CSO nor the BOD particularly considered that the development pace of emerging PV technologies (such as CIGS thin film) would be accelerated in the next few years. In fact, their selection of scenario B (policy driven) more or less reflects the current situation of *Newsun*: since their inception in 2007, the firm has not achieved mass production of CIGS; also, the potential market for CIGS is expected to be dampened by current industry downturn[85].

The technical and research experience of senior R&D managers may not necessarily reflect their views on future scenarios: the three senior R&D managers from *Solar one*'s, *Amorphous* and *Greenchild* all possess PhDs related to PV technologies, and all worked in the same research institute before joining their firms, yet they selected three different scenarios. Specifically, *Greenchild's* R&D Head's selection of scenario C (technology driven) is consistent with the firm's interest in pursuing technological leadership. In fact, this senior R&D manager's own expertise is in the field of c-Si technology[86] but he still acknowledged the accelerated development of emerging PV technologies compared to the other two managers. His comments are evidently influenced by the firm's current projects in CZTS and CIGS technologies.

Attitude towards PV technology development

[85]However, the case of *Newsun* may not necessarily represent the firm's pattern as in the case of *Solar one* and *Amorphous*, because *Newsun*'s BOD is not involved in the firm's daily operation.

[86] The R&D Head has a c-Si patent (under the firm's name) and the CIGS project was later allocated to a new division.

In the interviews of attitude towards PV technology development, senior managers were asked to provide comments on the direction and potential of PV technologies in the next five years **(Table 6.2**).

Table 6.2 Perception towards PV technology development in the next five years

Perception toward PV technologies and direction in the next five years					
	Solar one's **CTO**	*Amorphous*' **R&D Head**	*Newsun*'s **CSO**	*Greenchild*'s **R&D Head**	*FabPV*'s **CFO**; *Newsun*'s **VC BOD**
Senior managers' background	PhD in material engineering; previously work with ITRI (research)	PhD in optical engineering; previously work with ITRI (research)	BS in Physics, with operation but no research experiences	PhD in electric engineering; previously work with ITRI (research)	both are MBA; with investment experiences (in corporate or VC)
PV technologies in the next five year	c-Si (watch CIGS)	c-Si; niche market for a-Si	c-Si; potential of CIGS	c-Si (watch CIGS)	c-Si (watch CIGS)
potential technologies (directions) in the PV industry	c-Si related technologies - cost reduction in the PV value chain	c-Si (new structure e.g. HIT), a-Si thin film (e.g. BIPV)	CIGS (different manufacturing technologies)	new c-Si material (e.g., conductive paste); new-Si cell structure	All different PV technologies have the opportunities (including a-Si or CIGS thin film technologies and CPV)

Source: interviews and compiled by the author.

The influence of functional role

Although all senior managers generally agreed that the c-Si platform would be more likely to dominate the PV market in the near future, senior managers' functional roles firstly appear to differentiate their *ways of assessing the potential of PV technologies* in the next five years. The finding shows that while senior R&D managers tend to focus on the performance or the advantageous elements of the technologies, senior finance and business managers tend to evaluate the technologies more on the aspects

of markets and applications. For example, two senior finance/business managers[87] - *FabPV*'s CFO and *Newsun*'s VC BOD similarly commented that different PV technologies (including a-Si/μ-Si and CIGS thin film, and even CPV – Concentrator PV cells) all have distinct market potential, because PV technologies are application-oriented. Yet the four senior R&D managers' comments appear to be more restricted to the perspective of their firms' current technology platform. Basically, the four senior R&D managers held reserved opinion on the potential of CPV and other PV technologies in the next five years. For example, senior R&D managers of the two thin film firms (*Amorphou*s and *Newsun)* were more negative about the competing thin film technologies and emphasising the potential technological advantages of their firms' thin film technology over the next few years[88]. Generally, these senior R&D managers' comments about the potential of PV technology development reflect the focal R&D issues and goals of the firms' domain technologies[89].

The influence of firm context

The three senior R&D managers of *Solar one*, *Amorphous* and *Greenchild* have similar educational, technical and research experience, yet their views on technological opportunities are different. For example, when comparing the senior R&D managers of the two c-Si firms it is interesting to note that while *Solar one*'s CTO noticed issues along the supply value chain and acknowledged the cost-down

[87] *Amorphous'* GM didn't provide specific answers. *Solar one*'s deputy CFO expressed his unfamiliarity with PV technologies (he was new to the industry).

[88] It is interesting the two senior managers expressed strong negative views towards the other thin film technology that the firm didn't choose in the first place.

[89] As discussed in Chapter 5, key R&D issues and goals for the c-S- technology include new materials and development of new cell structures. In this sense, the *Solar one* CTO's response appears to be more concerned with the overall PV industry, which can be related to the firm's current product offerings. Key R&D goals and issues for thin film technologies include the improved deposition technique and low cost packaging. For CIGS thin film, although the potential for efficacy is higher than a-S- thin film, there is another issue regarding improved stability for commercial-scale production.

potential from downstream PV systems, *Greenchild*'s R&D Head emphasised the development of related c-Si cell technologies such as new materials for conductive paste and new cell structures. Therefore, although senior R&D managers in the same industry (and the same technology group) may share opinions on the general direction of technological development, their propensity of viewing future opportunities may still diverge and are not necessarily determined by their technical and research experience. Rather, their perspectives may be more influenced by the firm- specific context such as the possession of resources and capabilities[90].

Summary

The findings from assessment of senior managers' opportunity recognition suggest that there is selective attention at the senior manager level. Specifically, senior managers' responses to short-term market signals suggest that their initial attention towards the external environment is associated with their functional roles. The divergence between different corporate functional roles also shows in the basic approach of how senior managers assess the potential of technologies.

The influence of senior managers' current organizational context is particularly revealed in market scenario analysis. The evidence suggests that senior managers' framing of the long-term prospect can be more related to the firms' specific context rather than senior managers' functional roles of prior working experience[91]. This

[90] Compared with *Greenchild*, Solar one is superior in vertical integration and access to customers as discussed in Chapter 6. Although in Chapter 6, the comparison of resources and capabilities is conducted for the three c-Si firms only – but the differences in firm scale and performance between *Solar one* and the thin film firm *Amorphous* are obvious.

[91] As for the possible effect of tenure on the influence of the corporate perspective, data shows that the four senior R&D managers are indeed the firms' founding management team. However, the two senior finance managers are relatively new to the firms compared to the R&D managers, and have no prior

finding is in line with senior R&D managers' attitudes towards technology: their opportunity recognition of PV technology development over the five years is more influenced by firm –specific context, such as the choice of domain technology and current resources/capabilities, rather than their technical and research experience.

As discussed earlier, the concept of selective attention proposes the heterogeneity of the judgment and decision process among firms by using two categories of explanation: the pattern can be influenced by individuals' characteristics in perceiving the environment, or the pattern can be more driven by the mechanism of organizational identification. Here the findings suggest that senior managers' discrimination regarding short-term salient signals and effects can be generally predicted from their functional roles and prior working experience. However, in terms of framing long-term opportunity, organizational context can be more influential in the effect of selective attention.

This finding is supported by both behavioural decision and TMT perspectives: firstly**,** the accessibility of the decision context suggests that individual decision makers' (senior managers) perception can be influenced by their specific organizational context (Kahneman, 2003b). Secondly, the process of acquiring experience from an organization suggests that senior managers can adapt to the familiar stimuli present in their organizational context (Starbuck & Milliken 1988).

However, this finding can be better explained by the concept of decision makers using different frames in the framing process. In perceiving opportunities, functional roles

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experience in the PV industry. In the interviews, both the CFO of *FabPV* and the senior finance manager of *Solar on*e showed attempts to learn about the industry and adapt to the firm's culture – which may also illustrate a strong corporate influence – despite their relatively short tenure in the firm.

and prior working experience can be acted as "background" filters (Starbuck & Milliken, 1988). Thus role-based expertise may be associated with the initial search and scanning of the opportunities. However, the expertise associated with professional training and experience may not always be the effective frame to use for decisions under uncertainties (Kahneman & Klein, 2009; March, 2010). The "foreground" filters, including the organization's goals, expectations and operating procedures (Cyert & March, 1992) may impose a greater influence on judgment and implementation strategies, which would be reinforced over time. Therefore, when faced with making decisions under uncertainties in the same organization, the background filters (expertise) may tend to be diminished while the frame derived from the foreground filters prevails. The implication for firms' decision for new capability investments is that selective attention at senior manager level may not be as influential as selective attention in the organization.

6.2 Why selective attention may not necessarily be sufficient

In the interviews, senior managers indicated that competitors' moves are the most salient signals that may influence the firm's investment decisions regarding new technologies. In the analysis of selective attention towards competition, senior managers' comments are compared with relevant objective data about their targeted competitors.

Perception towards competitors

The senior managers of two large c-Si firms – *Solar one* and *FabPV* – considered their competitors based on their comparative position in the worldwide PV cell shipment. Thus the first-tier Chinese c-Si PV cell firms are regarded as their competitors. Although the senior managers of *Solar one* and *FabP*V declined to directly name specific firms[92], it is reasonable to compare the top two Chinese c-Si with *Solar one* and *FabPV* (**Table 6.3**).

Table 6.3 *Solar one* and *FabPV* in comparison with perceived competitors

[92] Even with the confidentiality promise in conducting the interview, as senior executives of the public firms, they were conscious about their comments on their peer firms. But they did mention the term of "first-tier Chinese firms" as main competitors.

Solar one and FabPV comparison with perceived competitors

	Solar one	**JA Solar (Chinese)**	**Suntech (Chinese)**	***FabPV***
WW solar cell shipment (2011) ranking *1	6	2	3	8
Capacity(MW)	Cell 1,500; wafer 500; module 100	Cell 2,400; wafer 1,600; module 2,400	Cell 2,100; wafer 300; module 500	Cell 1,300; module 50
Founded date	1981 (entry solar 2000)	2005	2001	2005
Market Type	OTC listed (Taiwan)	NASDAQ (US)	NYSE(US)	TSE listed (Taiwan)
Financials*2				
Revenue(US Million)	$955	$1,705	$3,096	$697
Net Income	-83	-42	-202	-98
Margin (Net Income)	-8.70%	-2.40%	-6.50%	-14.10%
Debt/Equity ratio	0.7	3.5	4.2	0.5
R&D Expense (% Sale)	1.14%(2011);1.28%(2010)	0.6%(2011); 0.5%(2010)	1.22%(2011);1.39%(2010)	0.54%(2011);1%(2010)
Patents(US, EU, AU) *3				
applications	5	0	21	4
granted (until Mar	1	0	1	0
earliest filing date	2007	N/A	2007	2010
IPC (Major)	H01L31	N/A	H01L31, H01L 21	H01L31
IPC (others)	B65G	N/A	H01L23, H01L29, C23D	C07D

**1 : Solarbuzz, January 2012*

**2 : company filings as of March 2012*

**3: Patent Lens*

Source: firms' annual reports, various industry sources and compiled by the author.

Firstly, the two firms' senior managers' remarks about their Chinese competitors' financing capabilities appear to be correct. According to comments from *Solar one*'s deputy CFO and *FabPV*'s CFO, given the recent tide of bankruptcies in the solar PV industry, financial strength – particularly liquidity – is important during periods of industry downturn. Indeed, financial data shows that generally the two Chinese firms have much higher debt/equity ratios than *Solar one* and *FabPV* (Nomura, 2011). But secondly, their comments about the top Chinese firms' technological investments seem to be leaning towards the impression of second-tier Chinese PV firms. Although *Solar one*'s CTO admitted that one of the first-tier Chinese PV firms – Suntech – is leading in terms of patenting, both he and *Fab*PV's CFO claimed that Chinese PV firms were generally behind in terms of quality manufacturing and were inclined to buy external technologies rather than develop their own due to the high turnover rate

of skilled engineers. From the patent application record, it indeed seems that JA Solar did not focus on patenting in comparison to other firms over the past few years. Yet the firm had much higher sales and better margins, and actually increased its R&D spending in 2011 (while all other firms reduced R&D expenses in the same year). In fact, JA Solar enjoyed such impressive growth during the industry downturn in 2011 that the firm recently announced its R&D partnership with one of China's leading research institutes (EnergyTrend, 2012). As for the other firm – Suntech – the firm has apparently invested more in R&D than its counterparts. The propensity to emphasize technological development is considered to be associated with the firm's long-term collaboration with academia (the University of New South Wales in Australia, one of the pioneer research institutes in PV technology). Moreover, compared to the two Taiwanese firms- *Solar one* and *FabPV*, Suntech has higher numbers of patents, in more diversified categories in terms of IPC[93].

Greenchild's R&D Head also said that the firm's competitors were first-tier Taiwanese firms (he particularly indicated *FabPV* in this remark) in terms of business, and the leading German PV firm – Q-cells – in terms of technology (**Table 6.4)**. Q-cells has long been regarded as the technology leader in the PV industry: the firm has invested in diversified PV technologies, including c-Si, a-Si thin film and CIGS thin film technologies[94]. In terms of patent records, Q-cells leads by some significant distance from *Greenchild*. The fact that *Greenchild*'s R&D Head perceives Q-cells to be their competitor implies the firm's value in terms of technology leadership. Rather than viewing Q-cells as a direct business competitor, *Greenchild*'s R&D Head

[93] Although patents may not necessarily constitute barriers in the industry, they do represent technology investments.

[94] However, recently the firm has suffered from huge losses and has just filed for bankruptcy protection (a few months after my interview with *Greenchild*'s R&D Head).

admitted that it would be more appropriate to refer to them as supplying a technology benchmark for the industry.

Table 6.4 *Greenchild* in comparison with perceived competitors

Greenchild comparion with the perceived competitors		
	Greenchild	**Q-cells**
WW solar cell shipment (2011) ranking *1	Tier 2	Tier 1 (not in top 10 in 2011)
Capacity(MW)	600	Cell 1,100; CIGS 75
Founded date	2004	1999
Financials*2		
Net Income	-87(US Million)	-845.8 (EUR Million)
Debt/Equity ratio	0.9	34.6
Patents(US, EU, AU) *3		
applications	1	27
granted (until Mar 2012)	1	4
earliest filing date	2009	1999
IPC (Major)	H01L21	H01L31, H01L21
IPC (others)	N/A	H04Q,H04B
**1 : Solarbuzz, January 2012*		
**2 : company filings as of March 2012*		
**3: Patent Lens*		

Source: firms' annual reports, various industry sources and compiled by the author.

A similar situation applied to the case of the R&D Head of *Amorphous*. The senior manager consider Taiwanese a-Si thin film firm –Nextpower as the main competitors. Yet he admitted that this competitor is much bigger in terms of capacity and patenting **(Table 6.5**). Thus the senior R&D manager said that he also regards the competitor as a reference point in terms of production and technological progress for a-Si thin-film products.

Table 6.5 *Amorphous* in comparison with perceived competitors

	Amorphous comparison with perceived competitor		
		Amorphous	**Nexpower (Taiwan)**
	Estimated production capacity (2011) *1	40MWp	100MWp
	Founded date	2007	2005
	Market Type	Private	Private
	Patents *2		
	applications (US and WO)	0	8
	granted (until Mar 2012)	0	3
	earliest filing date	N/A	2008
	IPC (Major)	N/A	H01 L31, H01L 21, H01L25
	**1 source: ECJRC, PV status report 2011*		
	**3 source : Patent Lens*		

Source: firms' annual reports, various industry sources and compiled by the author.

The CSO from the CIGS firm *Newsun* mentioned Miasole – a US CIGS thin film firm – as being their competitor (**Table 6.6**). However, Miasole is a high-profile CIGS firm with an aggressive patenting strategy (67 US patent applications and 15 granted patents), while *Newsun* has zero patent applications up to now. Besides this huge gap in patenting, the two firms adopt different manufacturing technologies for CIGS thin film products[95].

Table 6.6 *Newsun* in comparison with perceived competitors

[95] The two firms' CIGS thin film production is similarly based on the "continuous sputtering process", but with different proprietary process technology.

	Newsun comparison with the perceived competitor		
		Newsun	**Miasole (US)**
	Estimated production capacity (2011)*1	N/A	50MW
	Founded date	2007	2001
	Market Type	Private	Private
	Patents *2		
	applications (US and WO)	0	67
	granted (until Mar 2012)	0	15
	earliest filing date	N/A	2009
	** 1: ECJRC, PV status report 2011*		
	**2: Patent Lens*		

Source: firms' annual reports, various industry sources and compiled by the author.

These senior managers' perception of their competitors reflects how they position their firms in the industry. They tend to view competition in terms of their firms' current position within the industry. Basically, their views appear to map the standard grouping of players in various PV industry analyses (EPIA, 2011; IEA, 2010; MOEA, 2010). For example, senior managers of the three c-Si firms did not consider the emerging PV technology firms or the new vertically-integrated PV firms (from upstream or downstream) as potential competitors. Senior managers of the two thin film firms did not consider c-Si firms to be competitors; however, according to senior managers' (*Amorphous*' GM and *Newsun*'s CSO) remarks about their potential market, their target markets place them in direct competition with the c-Si firms. These firms' definition of competitors tends to be limited to the firm's current business focus. Further, their interpretation of the competition effect may not necessarily reflect the targeted competitors' behaviour. Therefore, despite these managers' claims about the influence of their competitors' moves on their investments in developing new capabilities, in reality these firms' decision behaviours may not necessarily be

predicted as being influenced by the actions of their perceived competitors.

The anchoring bias

As competitors are perceived as reference points for industry development or as internal justification of the firm's strategic action, here the biased perception towards competitors can be illustrated by the *insufficient adjustment* from the *anchoring heuristics*[96] . In fact, the choice of a target anchor may not necessarily be an issue if decision makers are aware of the anchoring effect (Kahneman, 2011). But problems arise when senior managers only selectively compared certain aspects of the competitors with their firms' perceived position in the industry. The difficulty of adjusting these anchoring biases suggests that problems may occur in the evaluation of the complex system (Tversky & Kahneman, 1974). For example, when comparing competitors' successful strategic action, senior managers may overestimate the probability that the same strategy would succeed in their organisations, given biased belief that their firms are equipped with similar or superior resources and capabilities. For example, it could be misleading for *Amorphous* to pursue the same strategy as Nextpower. On the other hand, senior managers may underestimate the risk associated with a particular product strategy adopted by the competitors, given biased belief that every part of the project would function as expected. While the risk in parts of the project may look low, the overall failure rate for the project could be much higher in different organisations. For example, while anchoring Q-cells' success in developing both c-Si-and thin-film technologies, the risk for *Greenchild* to adopt the same product strategy could be much higher[97].

[96] Please see the discussion of anchoring heuristic in Chapter 2.

[97] Although Q-cells announced bankruptcy in 2012, the firm's technological capability was still a valuable asset when the firm was required by a Korean PV firm later.

Search activities

Here five search activities including collaboration with research community, referencing worldwide technology roadmap, experimental projects, working with active customers and working with outside technology partners are examines. These activities are selected because they are relevant to exploration and new capability development in the firms[98]. The four senior R&D managers were asked to provide the weightings and comments on the relative importance of these search activities to their firms **(Table 6.7).** Basically all these senior managers are the head of R&D department, therefore their answers should reasonable represent their firms' search activities both in the planning and execution aspect. Their responses are also cross-examined with their firms' data and third-party interviewees' comments.

Table 6.7 Firms' search activities

Firms' search activities				
	Solar one	***Amorphous***	***Newsun***	***Greenchild***
Senior R&D managers' background	PhD in material engineering; previously work with ITRI	PhD in optical engineering; previously work with ITRI	BS in Physics, no research experience	PhD in electric engineering; previously work with ITRI
Collaboration with research community	★★(critical, but Taiwan is weak)	★★	NIL	★★
Reference WW industry technology roadmap	★★★	★★★	★★★	★★★
Experimental projects	★★	★★	★	★★
work with active customers	★★★	★★★	★★	★★ (Short term only)
work with supplier/outside technology partners	★(cautious-friend or enemy)	NIL	★★ (co-work with the solution provider)	★(only project base)
★ indicates the perceived impact level				

The author summarized these weightings based on senior managers' evaluation: the comparison of their

[98] In the interviews, I also checked with the senior managers if there are other search activities in their firms. They responded that basically the listed items basically cover all the current activities. .

firms' search activities.

★ :Less important; ★★:Important; ★★★:Relatively important..

Sources: interviews and compiled by the author.

Roadmap

Among the five search activities, the four senior R&D managers similarly indicated that referencing the industry technology roadmap is the most important search activity. In regard to the two c-Si firms, there is an industry-standard roadmap for c-Si technologies, and the two senior R&D managers regard this roadmap as a guide for their technology development and planning process[99] Although there is no standard industry roadmap for thin film technologies due to the variety of the technologies involved and the limited industry participants, *Amorphou*s' R&D Head said he collected various industry sources and self-compiled the technology roadmap. As for *Newsun*, the CSO said that although he considered the current CIGS technology roadmap to be mostly just claimed lab results (because of the lack of evidence on volume shipments), the technology roadmap (from different industry sources) is still the firm's number one reference point in projecting the firm's technological progress. The fact that referencing shared worldwide technology roadmap is the most highly weighted search activities among firms implies the common industry influence on firms' attention towards the technological progress. This factor provides support for illustrating firms' similarities in capability investment pattern as discussed in Chapter 5.

[99] They all pointed to the same industry sources, such as the ITRPV-International Technology Roadmap for Photovoltaic) SEMI. 2011. International Technology Roadmap for Photovoltaic (ITRPV.net): SEMI PV Group , SEMI. 2012. International Technology Roadmap for Photovoltaic (ITRPV.net)SEMI PV Group..

Working with active customers

This activity was generally weighted second to the activity of reference roadmap among the four firms. Basically, the search activity of working with active customers could be related to the propensity of exploring opportunities from downstream PV system. These senior managers' comments only partially reflect their firms' experience in accessing customers and propensity in developing related capabilities. For example, while *Solar one* does have more experience in reaching end customers than other firms, *Amorphous*' response is consistent with the firm's recent BIPV (footnote) project. *Greecndhild*'s response of "short-term only collaboration" implies that working with active customers may not be considered as critical in the firm's search activity. In fact, the firm did announce the related investment in downstream system in 2011. As for *Newsun*, although the senior manger indicated the importance of this activity, the firm has not had evident activity working with customers since the firm's inception in 2007[100].

Collaboration with research community

Two distinct patterns are found among the four senior R&D manager in the collaboration with the research community: while the senior R&D managers of *Solar one*, *Greenchild* and *Amorphous* all stated the importance of working with research communities in searching for new technological opportunities, *Newsun*'s CSO (also a former R&D Head) stated that collaboration with research communities was not necessarily critical, for the following reasons: firstly, the current threshold for the

[100] The comments are from *Newsu*n's BOD (also a VC) and from other third –party interviewees.

firm's CIGS thin film technology is the volume production process, which is not necessarily something that can be addressed by the research community; and secondly the academia/research institutes in Taiwan are usually not equipped with the appropriate environment. From the firm's perspective, and judging by its current situation, these reasons sound legitimate for *Newsun*. However, as the senior manager emphasises the importance of resolving the firm's current technology problems, he may overlook the potential value of the research environment in exploring new ideas, something that is more appreciated by the other three R&D managers.

Similarly, two different patterns are reflected in these senior managers' attitudes towards the partnership with the research community in MOEA projects. On the one hand, *Newsun*'s CSO stated that the main purpose of applying for government projects was for better public relations, and that the partnership with research communities merely follows the requirements for MOEA projects[101]. On the other hand, the other three senior R&D managers considered the collaboration with research communities in MOEA projects to be critical: *Amorphous*' R&D Head said that he worked closely with a professor's research team in the firm's a-Si/μ-Si thin film project; *Solar one*'s CTO confirmed that the firm utilized the small c-Si cell production line in ITRI for experiments on new cell structures[102]; and *Greenchild*'s R&D Head stated that the firm worked with two different research centres in ITRI for the CIGS thin film project.

The activity of collaboration with research community is generally an indicator for exploration of new technologies. Here the senior mangers' responses show the

[101] In fact, the research institute's role in *Newsun*'s MOEA project being mainly concerned with testing and documentation is confirmed by the firm's partner, ITRI.
[102] The experimental production line in ITRI is also confirmed by the project leader of ITRI.

influence more from individuals' experience than from firm-specific context. The differences between *Newsun*'s CSO and the other three managers can be traced back to their educational and professional backgrounds. The prior working experience of *Newsun*'s CSO are mostly related to manufacturing and production-line management, while the three senior R&D managers at *Solar one*, *Amorphous* and *Greenchild* have similar working experiences with the research communities prior to joining the firms.

Experimental projects

The implementation of experimental projects is regarded as a direct indicator of the firm's new capability development. Here this search activity was similarly received moderate weighting among the four senior R&D managers. Generally, these managers' conception of the experimental project is associated with their current technologies, rather than exploratory technologies[103]. For example, all the senior managers mentioned experimental projects in the context of the fine-tuning of the manufacturing process for the existing technology platform. As for the two firms (*Greenchild* and *Amorphous*) with the evidence of exploration projects, both R&D heads recognized the practice of the MOEA project and the CZTS project (*Greenchild*) as another mode of experimentation. But they did not regard these projects as the firms' experimental projects for "normal" search activities[104]

Attitudes towards partnership

[103] For example, *Solar one*'s CTO mentioned experimental projects on improved cell structures and material composition (on the existing c-Si platform). *Newsun*'s CSO stated that to achieve mass production for CIGS, experimental projects are conducted on a regular basis at the firm.
[104] They didn't mention the MOEA projects until the author asks.

Four distinct patterns were found with respect to the activity of working with suppliers or outside technology partners. *Solar one*'s CTO said that because c-Si technology is relatively mature, the firm is cautious about working with outside technology providers. Apart from the partnership with the research community in MOEA projects, the firm's only (public) technology partnership was a project with a US-based R&D lab in 2008[105]. *Greenchild*'s R&D Head indicated that the firm would enter some project-based partnerships on alternative PV technologies, but would not consider external partnerships involving core technologies on the c-Si platform. Apart from the partnership with ITRI in the MOEA project on CIGS, the firm's only technology partnership was the CZTS thin film project with two foreign companies in 2010. *Amorphous*' R&D Head stated that apart from partnerships with the academic community in MOEA projects, there is little co-operation with the firm's technology provider. The R&D Head emphasized that the firm's thin film module efficiency rates have surpassed its supplier's record[106][107]. As for *Newsun,* the firm's CSO described the importance of partnering with an outside technology partner. In fact, the firm has been collaborating with an equipment supplier in developing the firm's CIGS manufacturing technology since 2008, and the partnership has strengthened to the point that the supplier later became the shareholder of the firm[108]

There is evidence of collaborating with outside technology partners in the three firms' (including *Solar one*, *Amorphous* and *Greenchild*) projects of new capability development. Thus this search practice can be an indicator of firms' exploration

[105] The research project can be related to *Solar one*'s acquisition of a polysilicon wafer firm in the US.
[106] According to *Amorphous*, the firm purchased a turn-key thin film solution from a German firm, and the supplier had little involvement on the fine-tuning of the manufacturing process.
[107] Amorphous' GM made the same remark.
[108] From the perspective of Joint Venture partnership, this technology collaboration can be categorised as "internal" rather than "external" partnership. Also, the CSO implied that a certain level of conflict on the co-developed know-how: while *Newsun* regards it as the firm's own property, the partner plans to sell the solution to other potential customers in the future.

activities. Also the differences in these firms' partnership mode suggest that collaboration with external partners could be the most differentiated search activity among firms. However, given the minor weight indicated by the theses senior managers, this activity is not considered as a particularly critical practice in the firms' search activities.

With respect to the factors influencing the firms' technology partnership, it appears that the firms' past partnership experience may affect their preferences regarding modes of partnership with outside technology providers. However, these senior managers' responses actually reflect the characteristic of the targeted PV technology in their collaboration projects. For example, regarding the projects on the c-Si platform, the relatively mature technology with available turn-key equipments, firms seemed to prefer acquisition (such as *Solar one*'s acquisition of a polysilicon wafer firm) or in-house development, like *Greenchild*. The rationale follows one of the key features of PV technologies – the importance of manufacturing know-how[109]. A similar situation applies to a-Si/μ-Si thin film technology[110]. As for the emerging PV technologies, partnership with outside technology partners can be a feasible way to share the development risk from the perspective of practical consideration. For example, for its new capability investments in emerging PV technologies, *Greenchild* chose to develop CZTS thin film technology[111] with partners on a project basis. Similar project-based mode with ITRI is applied for the five-year government-funded CIGS project[112] In the case of *Newsun*, as CIGS is the firm's core technology

[109] For example, even using the same equipment, the yield rates may be varied significantly among firms.
[110] Compared with other thin film technologies, a-Si/μ-Si thin film technology is relatively mature, with standard turn-key solution equipment.
[111] Compared with CIGS, the CZTS thin film technology is in much earlier lab stage.
[112] Compared with *Newsun*'s CIGS product, *Greenchild'*s CIGS project uses printing process technology which is in a much earlier lab stage.

platform, the joint venture partnership with the technology partner suggests the benefits of both technological and financial risk-sharing in the longer term process of achieving mass production. Therefore, the seemly firm-specific pattern in partnership mode is actually derived from the characteristics of the chosen technologies in the industry.

The industry influenced search

Generally, the similarities in terms of the weightings of the search activities suggest a stronger influence from the industry than the firm specific context. Among these activities, collaboration with external technology partners can be a more viable indicator for firms' new capability development and a potentially differentiated search practice. Yet the issue is that this search activity is similarly received minor weighting among these firms. With respect to the influence of individual experience, the only significant difference shows in the activity of collaboration with research community. However, the three senior managers (those with research experience) did not weight this collaboration particularly highly in their search activities. This fact implies that industry practice can still be more influential than the individual's prior professional experience.

Summary

Firstly, the finding from senior managers' perception towards competitors suggests that there is presence of selective attention with firm-specific patterns. However, while the effect of selective attention is illustrated in the way senior managers selectively perceive some aspects and neglect others of the competitors, the *anchoring*

bias towards competitors raises the question if such selective attention is relevant to firms' decision rationale in investing new capabilities, as claimed by these senior managers.

Secondly, senior R&D managers' responses of their firms' search activities show that their prior technical and research experience may influence certain search practice such as the link with research community. But overall the evidences indicate that senior managers' search patterns can be more influenced by industry practice than by individuals' prior experience[113]. Moreover, there is no significant evidence showing firm- specific pattern in the search activities. In particular, these senior R&D managers similarly indicated that referencing the industry technology roadmap is the most important search activity. The implication is that within the same industry, firms' propensity in allocation of attention (search) may not necessarily be sufficient to explain their variation of new capability investment patterns. In the next Discussion and Conclusion Chapter we will discuss what potential factors other than selective attention may explain firms' decision to invest in new capabilities.

[113]Senior R&D managers' expertise acquisition from the same industry may also explain: the similar pattern of search activities may reflect the fact that with the qualifications of expertise in the specific domain, senior managers may be trained with similar knowledge and practices that are accessible in this environment. In particular, the Solar PV industry is characterized as a highly professional-centric industry. This concept is also illustrated in the institutional perspective (DiMaggio & Powell, 1983).

Chapter 7

Discussions and Conclusions

Introduction

This research finds that firstly, the concept of framing defined by behavioural decision theory of narrow framing and prevailing frame may help explain the emphasis on exploitation. Secondly, with the broad definition of framing as the interpretation of decision problem; this research finds that the organizational decision perspective of selective attention does exist at the firm and senior manager level, but such differentiated framing is not necessarily associated with different choice patterns. As the role of framing may only partially explain firms' capability investment decisions, it then leads us to identify other factors that may explain the decision to explore.

Previous empirical findings actually provide some potential directions of further investigation. In Chapter 4, judgemental heuristics and biases were found as the stylized principles to explain firms' similar decision pattern. It implies the whether or not the use of *deliberate heuristics* (as suggested by the prescriptive view of behavioural decision perspectives) may encourage exploration? In Chapter 5, the finding of loosely coupling framing and choices suggests that differences in choices may not necessarily be related to the pattern of selective attention. It implies the direction of examining the decision's own dynamic in the process (March, 1994; Vidaillet, 2008). In Chapter 6, organizational context is found to be more influential than individuals' professional experience in opportunity recognition, which suggests that the design of organizational mechanism may encourage exploration.

As a consequence, the potential role of deliberate practice is derived from the prescriptive views of both behavioural and organizational decision perspectives. Specifically, “deliberate” corresponds to the “deliberate heuristics” and “practice” emphasises the design of the decision practice and organizational mechanism. Here the suggestion is that deliberate practice, rather than framing has a stronger influence on the decision to explore.

This finding moves the initial emphasis of framing more towards the role of deliberate practice in influencing the decision process. Firstly, the role of framing explains the potential biases in the judgement and decision process, which is central to the design of mechanism that can help overcome the limitations of framing. While the organisational decision perspectives assert that the factors influencing the organisational decisions are interdependent and connected by the contingency of the decision context, the behavioural decision perspectives provide stylized predictions of heuristic judgement. Secondly, appreciation of the role of deliberate practice stems from a more pragmatic standpoint. It incorporates the psychological mechanism suggested by the behavioural and organisational decision perspectives. The suggested mechanism of deliberate practice implies the application of rational model in the organisation as a process not necessarily as an analysis of the decision outcome (March, 1994). Therefore, by investigating the role of framing and deliberate practice, this research contributes to unpack the relationship between descriptive and prescriptive views of the decision making process.

This concluding chapter begins with a discussion of deliberate practice in Section 7.1, which is followed by a summarized discussion of the empirical results in Section 7.2.

Finally, Section 7.3 discusses the implications and examines the limitations of, and future directions to take from this research.

7.1 Deliberate practice

The discussion of deliberate practice starts with explaining the theoretical concept drawing from behavioural and organizational decision perspectives. Then the potential role of deliberate practice in influencing the decision to explore is illustrated with the empirical finding from the case of *Greenchild*.

The prescriptive view of decision process

Previous discussions about the behavioural and organizational decision perspectives illustrate that narrow framing coincides with organizations' tendency to favour exploitation. Here the prescriptive view of behavioural and organizational decision perspectives informs us to design and adopt deliberate practice to overcome the judgemental and adaptive mechanism in the decision process.

The controlled System 2, deliberate heuristics and procedural rationality

Relative to the automatic System 1, the controlled process of System 2 is characterized by more abstract reasoning, and less inferences from experience (Evans, 2008; Kahneman & Frederick, 2002; Stanovich & West, 2002). System 2 is also referred to as the "corrective thought" (Kahneman, 2003b:711). Therefore, under conditions that are vulnerable to judgmental biases, the suggestion is to utilise the analytical process of System 2 to override the associative process of the System 1 process (Kahneman & Frederick, 2005; Stanovich & West, 2002). Using the definition that heuristics are the simplified procedure or logic rules that decision makers use to solve complex problems, the *deliberated heuristics* generated from

System 2 differ from the heuristics (representative, availability, anchor and affect heuristics) described in the System 1 judgment process (Frederick, 2002).

From the organizational decision perspective, the procedural aspect in the decision process refers to the "planning program" and is distinguished from the substantial aspect as the "planning program for the problem-solving process itself" (March & Simon, 1958: 140). While the substantial aspect of the problem depends on the context of a specific decision problem, there is certainly a recognizable pattern for the procedural aspect. In other words, the procedural program can be routinized and rationalized to a certain degree in the organization (March & Simon, 1958). This concept of *procedural rationality* emphasises the design for the decision process (Simon, 1996b) and coincides with the behavioural decision perspective in the developing deliberate heuristic from the operation of System 2.

Manipulated attention and attention management

For the general prescription, behavioural decisions scholars propose "manipulated attention", meaning ideas such as increasing the exposure to statistical thinking, or practice with the logic rules to stimulate the functioning of System 2 (Kahneman, 2003b; Kahneman & Frederick, 2005). Further, on the application side, it is suggested that the process of the debiasing strategy begins with identifying the heuristics utilized, and the biases resulting from the underlying assumptions. For example, in the case of the availability heuristic, the attention may need to be redirected to the less salient signals, which may be underestimated in the judgment process. In the case of overconfidence bias, it may help to reconstruct the decision task by deliberately considering alternative explanations and opposing evidence (Fischhoff, 2002).

Similarly, in the bias of anchoring, it is recommended that counter arguments are developed to compare with the established anchors in making judgments (Morewedge & Kahneman, 2010).

Compared with System 2, System 1 is relatively highly contextualised. The emphasis on System 2 operation seems to suggest the importance of "decontextualisation" in monitoring the functioning of System 1. For example, scholars have questioned the central role of "environmental alteration" in the desired direction of the cognitive and behavioural change (Stanovich & West, 2002). The point here is not to ignore the contextual factors, but to be critical about the influence of the context in the judgment and decision process. This understanding of limitation is necessary in considering the prescription for the "manipulated attention" (Kahneman & Frederick, 2005).

In the organizational decision process, the constraining aspects of the organization not simply relate to individuals' selective filtering process of, but can also sometimes be utilized as the mechanism for overcoming the potential bias from System 1 judgmental heuristics. Corresponding to the concept of manipulated attention, in the early study from March and Simon the concept of programmed stimuli has already been introduced as the deliberate mechanism to direct the attention of the organization (March & Simon, 1958). The notion of the "*management of attention*" refers to "changing the representation of the decision problems", and the allocation of attention to different solutions (to the decision problem) with different time-frames. For example, attention can be allocated to solutions that "produce the immediate consequences" and solutions involve longer time frame. (Simon, 1996b: 132, 161). Linking the concept of manipulated attention with procedural rationality, it is suggested that the procedural program can be more critical than substantial program

in directing senior managers' attention pattern (March & Simon, 1958).

Separate mechanism for exploration and the idea of experimentation

With respect to the design of organizational decision process in overcoming the potential bias toward exploration, scholars suggested the concept of "reducing interdependence" between exploitation and exploration programs (March & Simon, 1958). In other words, the mechanism for exploitation and exploration should be differentiated in the organizational practice. In March's own words, "whereas the mechanisms of exploitation involve connecting organizational behaviour to revealed reality and shared understandings, the recommended mechanisms of exploration involve deliberately weakening those connections" (March, 2008: 177). The reason for designing separate procedural program for exploration (March, 2008) lies in that if the procedural program is tied in with the organizational goal in the problem-solving process, it is inevitably influenced by selective attention in the organization (March & Simon, 1958).

This perspective of proposing separate mechanism for exploration reflects the idea of investing in small *experiments* that are not necessarily tied to the current and organizational programs and immediate business goals. Another advantage of small-sized experiments is that it allows the flexibility of adjusting criteria and goals in the search process. The concept is illustrated in Simon's notion of "designing without final goals" in which he emphasizes that the "exposure to new experiences" needs to "change the choice criteria" in the design of decision process (Simon, 1996b: 162).

On the conceptual level, it seems to deviate from the straight suggestion from the

behavioural decision perspective that decision makers should try to avoid the isolating effect in evaluating the exploitation and exploration projects (Kahneman & Lovallo, 1993). However, in reality when the primacy of System 1 is present, it can be difficult to implement the procedural rationality program for all investment projects. Thus on the design level, the deliberate mechanism (not tied to current organizational goals) as the supplemented procedure for evaluating new uncertain projects can be more viable and practical for implementation in the organization.

Deliberate practice

Here the idea of deliberate practice is introduced to capture the prescriptive views from the behavioural and organizational decision perspectives. Firstly, drawing from the concepts of deliberate heuristic and attention management, deliberate practice is characterized by "*specially designed*" and "*effortful*" activity. It differentiates from the heuristics immediate accessible in the judgemental process and the spontaneous adaptive mechanism in the organizations. Secondly, with a specific focus for exploration, the concept of separate mechanism suggests that deliberate practice is not necessarily linked to the evaluation of performance. That is, such deliberate practice for exploration may not necessarily generate *"immediate returns"* from the external environment. Rather, deliberate practice is motivated by the *"instrumental value"* of the potential in improving performance (Ericsson, Krampe, & Clemens, 1993)[114].

Table 7.1 summarizes the key concepts and mechanism proposed by the behavioural

[114] Here, the definition of deliberate practice is close to the concept utilized in the expertise research. In distinguishing deliberate practice and work, expertise scholars suggest that because the costs associated with work are greater, individuals tend to rely on existing knowledge and experience "rather than exploring new alternative methods with unknown reliability" (Ericsson et al. 1993).

and organizational decision perspectives.

Table 7.1 Deliberate practice as a prescription

	Key Concepts	Mechanism and applications
Behavioural decision perspectives	Not relying on the adaptive mechanism of automatic System 1, developing deliberate heuristics from controlled System 2 (Frederick 2000; Kahneman & Frederick 2005; Kahneman 2011)	Utilising manipulated attention to overcome judgemental heuristics derived from System 1 (Kahneman & Frederick 2005). Practicing the logic decision rules and debiasing strategy (Fischhoff 2002)
		Outsider view (Kahneman 2011)
Organisational decision perspectives	The design concept for the adaptation (to external environment) process (Simon 1996).	Managing attention : representation of the decision problem and process design (Simon 1996)
	Targeting "procedural rationality - the appropriate adaptive behaviour" (as opposed to "substantive rationality - the actual adjustment to environment") (Simon 1996 :25)	Procedural rationality incorporated into the decision routine (March & Simon 1958). Real options logic (Adner & levinthal, 2004; Kogut & Kulatilaka 2004), adjusting search criteria or aspiration level as the procedural rationality programs (March & Simon 1958; March 1994).
	Adaptation inefficiency (in favour of exploitation). "Reduce the interdependency" of programs between exploitation and exploration program (March 2008)	Separate mechanism; detachment of goals (Simon 1996, March 2008); Experimentation (March 2008).

Source : the author.

An example of deliberate practice – the application of the real options approach

Organizational scholars have proposed the application of the real options approach as a procedural rationality[115] (Adner & Levinthal, 2004; Kogut & Kulatilaka, 2004) which corresponds to the prescription from the behavioural decision perspective in mobilizing the deliberate heuristics from System 2 with the practice of logical thinking and analysis.

In an empirical study investigating how Merck employed the real options approach in evaluating the investment of a small biotech firm, the authors found that in the

[115] Certainly the procedural programs are not limited to the real options approach; there are other programs such as deliberately adjusting the internal search criteria and the aspiration levels (March 1994; March & Simon 1958; Simon 1996).

process of using the real options model, there are two potential problems that would significantly influence the option valuation: the first is "modelling assumptions" and the second is "determining the inputs" (Bowman & Moskowitz, 2001:774-775). The required capability for developing customized modelling analysis generally is beyond the capacity of organizations. Although the authors point out the limitations of using the real options approach as strategic analysis in the organizational decision context, they found that rather than improving the actual assessment for investments, the advantages of using the real option models are the implication for project design and the use of the option logic in rethinking the investment proposals for systematic search. In the authors' words, the use of the real options approach "encourages experimentation and proactive exploration of uncertainty"(Bowman & Moskowitz, 2001:777).

The insights from the Merck case illustrate the two concepts of viewing the option valuation as an example of deliberate practice. First, the value of the using the real options approach as deliberate practice does not lie in the rigid strategic analysis but in the deliberate heuristic of option thinking. Second, the option logic is linked with the concept of small or control-sized experiments, the classic advice for exploration investments (March, 2008, 2010). Therefore the option logic in the real options approach can be simply applied as a counter logic to correct the potential under-investment in new capabilities.

Deliberate practice in Greenchild

Here the investigation of deliberate practice in this research context focuses on the evidence of case firms' MOEA projects. There are two reasons for re-examining these

firms' MOEA projects: the one is that the mechanism of MOEA projects serves as a good comparison base to evaluate the case firms' attitude and practice towards technology development projects. The other is that previous finding has shown that there are two firms (*Greenchild* and *Amorphous*) with the evidence of developing exploratory technology in the MOEA projects. Following the concept of deliberate practice, the investigation focuses on two aspects: the first is that whether or not the two firms demonstrate the deliberate heuristics in the decision process; and the second is that if there is specific decision practice in place for exploration investments in the organisation.

The option thinking logic

It is not evident that the senior managers of *Greenchild* and *Amorphous* applied the strategic heuristic of the real options logic in the decision to invest in new capabilities: the two firms' decisions to invest new capabilities were not necessarily followed by applying the real options logic in concurrently evaluating existing and new capabilities(Kogut & Kulatilaka, 2001)[116].

However, the option thinking of *hedging* future opportunities with initial trial investments firstly shows in the two firms' decisions to utilize the MOEA projects to develop technologies that were not based on their existing platform. Here the external funding support in encouraging option thinking for exploration appears to work for the two firms (but not for the others)[117]. Further, this option thinking logic only applies to the two firms' investments in alternative technologies, not their core

[116] The suggestion of utilizing the option thinking of capability investments is the framing of core competence in the market evaluation,

[117] Both R&D Heads of *Greenchild* and *Amorphous* indicated that their firms would not invest in new technology projects (other than their existing technology platform) without the support of government funding.

technology investments. Particularly, the R&D Head of *Greenchild* stressed that the firm would not leverage government funding or external resources in developing the firm's core c-Si technology.

There is evidence of *staging of R&D investments* in MOEA projects: after making initial investments, the firms would wait for signals to decide whether or not to make further investments or to abandon the projects[118]. For example, *Greenchild's* R&D Head described that after the firm's MOEA polysilicon wafer projects ended in 2010, the firm discontinued its related investments in view of the continuing trend of dropping market price for polysilicon. On the other hand, *Greenchild* decided to make a subsequent investment – the five-year CIGS thin film project – after evaluating the results of the one-year CIGS pre-study project in 2010. With respect to *Amorphous*, the firm withdrew from the CIGS project (a year earlier then the expected completion date) because the firm found that the timeline for CIGS development was too lengthy.

Decision practice in the organization

While both the cases of *Greenchild* and *Amorphous* show the evidence of simple option thinking rather than the rigid strategic analysis, the next question is whether or not this option-practice of utilizing government-funded projects for new capability investments can be found on a regular basis. For *Amorphous*, after dropping the CIGS project before the initial commitment date, the firm shows no intention of applying other MOEA projects for new technologies other than the firm's current thin-film technology[119].

[118] As suggested by the real options theory.
[119] Comments from Amorphous' R&D Head.

With respect to *Greenchild*, the firm's option thinking practice can be observed not only in the MOEA projects but also in their decision process for new investments.

Firstly, evidence shows that *Greenchild'*s parent company and the associated firms have been the most frequent winners of MOEA projects (targeting exploration investments) over the past few years[120]. Further, insider sources (including a senior finance manager from *Greenchild*'s parent company, *Greenchild*'s VC, and the deputy CFO of another large electronic group) similarly indicated that *Greenchild*'s parent company has a specific practice in place for evaluating new ventures: while the company is accustomed to provide opportunities for the trial or experimental period of new ventures, if the unpromising outlook of a project persists for a certain period, then the company would ruthlessly kill the project to halt further losses. Judging from *Greenchild*'s composition of boards of directors[121] as well as from the comments from *Greenchild*'s senior manager and other third-party interviewees, *Greenchild* has indeed inherited this practice from its parent company.

The case of *Greenchild* illustrates a recognizable pattern of deliberately allocating resources for new investment projects in the decision process. In contrast to *Greenchild's* pattern, the tendency to rely more on certain individuals (executives or senior managers) than specific decision rules is observed in other firms. For example, *Amorphous'*s R&D Head implied that the firm's GM had the final call in all the firm's investment decisions, and that the potential problem is the GM is relatively conservative about exploration and reluctant to make new capability investments during industry downturn.

[120] Information from MOEA and MOEA officials.
[121] The majority of the firm's boards of directors are the executives from the parent company or its associated firms.

With respect to the other two firms (without new capability investments in MOEA projects), both the deputy CFO of Solar one and the CFO of FabPV emphasised the importance of the R&D Head or the CEO's personal commitment to convince boards of directors about the investment projects that have a high degree of uncertainty. As pointed out by *Solar one*'s deputy CFO, such personal endorsement is often necessary, because senior boards of directors usually prefer (and recognize) traditional ROI or payback periods in evaluating investment projects.

Therefore, the case of *Greenchild* shows that the decision practice for new investment projects is sustained by organizational mechanism rather than by the judgment of key decision makers. Although *Greenchild* (and the parent company) did not evidently follow the rigid strategic decision analysis such as the real options approach, the firm's practice differentiates its pattern from the others[122] and demonstrates the concept of deliberate practice: first, it can be regarded as "*specially designed*" for new capability investments. Second, there are evidences of "*consistent efforts*" in leveraging government funding (MOEA projects) for option investments in both *Greenchild* and the parent company. Finally, the characteristic of not being connected to "*immediate returns*" shows in that there is an explicit rule encouraging and allowing certain trial period for all new investments projects in the decision process.

Separated organisational mechanism for exploration

The case of *Greenchild* corresponds with the concept of the separated mechanism for exploration and exploitation: whereas the investments for exploitation are tied to

[122] At first sight, this finding seems to contradict the findings in Chapter 4 that *Greenchild* is similar to other firms in terms of its investment project evaluation. But the point here is that while the firm may follow some similar decision criteria in the process for new project evaluation, it deliberately allocates certain resources for investment in new capabilities.

current business programs, new capability investments are not necessarily bound with these current business goals. For example, the R&D Head of *Greenchild* described that MOEA projects would be both financially and operationally independent from the firms' current R&D activities. On the contrary, in the case of *Solar one*, the CTO stressed the relationship between the firm's MOEA projects and its current R&D projects. The firm's deputy CFO also indicated that the firm's MOEA projects might have been bundled together with the firm's R&D expenses, or the R&D department's projects in the investment evaluation process.

Further, the case of *Greenchild* supports the idea that exploratory projects could be positioned (partially) outside of the firm through collaboration with outside partners. Apart from the benefits of sharing risk and the cost of the irreversible investments for new capabilities development, here it is emphasised that the partnership mode for developing new capabilities provides a convenient organizational mechanism for separating the firm's existing projects from the exploratory projects.

In *Greenchild*'s CZTS project aiming at breakthrough technology (a new material composition for thin film technology), the firm teamed up with two strong technology partners – IBM, and Solar Frontier, a leading Japanese CIGS manufacturer. Also, through the partnership with two research centres (a material technology research division and a PV cell and system research division) in ITRI, *Greenchild* continued investing in the CIGS project after the one-year pre-study project[123]. The case of *Greenchild* shows the example of how partnership mode for new experimental projects serves as the separated organizational mechanism for developing new capabilities.

[123] *Greenchild* also decided to hire the project lead from ITRI after the one-year pre-study project.

Different from Merck's adoption of using the real options approach in evaluating investment decision (Bowman & Moskowitz, 2001), the case *Greenchild* demonstrates simple option thinking and practice embedded in the firm's decision process for new capability investments. The fact that *Greenchild* uses separate mechanism for exploration in a way sustains the mode for experimentation.

7.2 Discussion of the results

The discussion of results is organized into two parts: the role of framing and the role of deliberate practice.

The role of framing

This research argues that framing can explain the decision to exploit current capabilities, but is not sufficient to explain the decision to explore. While the general definition of framing refers to how choices are affected by the interpretation of the decision problem, here two phenomena derived from the framing effect are particularly addressed: the first is narrow framing, referring to the lack of consideration of the relevant consequences and opportunities when making choices. The second is the passive acceptance of the prevailing frame.

The finding that narrow framing leads to an overemphasis on exploitation is in line with the proposition from organization decision studies (Kahneman & Lovallo, 1993; March, 1991; March, 2008). Yet the underlying mechanism of the framing effect in influencing firms' capability investment decisions is less explored. In the theory of framing effect from the behavioural decision school, the terms "framing" and "frame" are similarly treated as the same construct (Kahneman & Tversky, 2000). In this research, the role of framing addresses two distinct concepts: "framing" refers to the process of constructing the meaning, whereas "the frame" refers to the specific perspective adopted by the decision makers. Thus the principle of heuristic judgment and the associated biases can be applied in the investigation of the framing process, whereas the prevalence of a decision frame illustrates how the assessment of decisions

is directed towards a particular perspective. This research suggests that in real-world settings, decision makers may use different frames in the framing process. Through integrating the investigation of the "framing process" and "the decision frame", the contribution of this research lies initially in differentiating the two concepts of "framing" and "the frame" in order to illuminate influences in the judgment and decision process.

Diminishing sensitivity to uncertainty and the conditions for the prediction

From the framing of the external environment, the argument that framing explains exploitation is based on three observations from the empirical work in Chapter 4 and Chapter 5: the first is *the diminishing sensitivity to uncertainty*. In the research context of the PV industry, decision makers' perceived effect of policy uncertainty on new investments has been decreasing, after experiencing similar patterns over the past few years. The insight of this observation lies in that it questions the central role of perceived environmental uncertainty in influencing investment decisions.

The research identifies the conditions for this prediction: *the pattern and the source of the uncertainties* in the investigated industry context. The pattern is defined by the temporality of the incidents in the uncertainty. This research suggests that the framing of the uncertainty effect on investment decisions can be subject to the point of time near or distant from the threshold points[124] of the uncertainty (Kahneman & Tversky, 1979; Tversky & Fox, 2000 In the context of the PV industry, the pattern of this

[124] Referring to the point of time when the probability of uncertain events turns from impossibility to possibility or from possibility to certainty. In the context of the PV industry, another example is that the timing of the first launch of large-scale government incentive measures can be viewed as the point of time when possibility turned to certainty, indicating a stronger effect than the later period following the continued implementation of similar programs.

policy uncertainty can be applied to the prediction of diminishing sensitivity to this perceived uncertainty. For example, the first wave of government incentive cuts started in 2008-2009, and has been related to the first PV industry downturn. Then, after a short period of recovery, the PV industry experienced the second industry downturn resulting from another wave of government spending cuts. Policy uncertainty remains a critical factor in influencing the development of the PV industry, but senior mangers responded that after experiencing recurring policy uncertainty over the past few years, the perceived effect of policy uncertainty in influencing the firms' investment decisions had been reduced[125].

In terms of the source of uncertainty, the term refers to the relationship between the source of the uncertainty and the decision makers' competence area. For example, c-Si PV cell manufacturing is the competence area of Taiwanese PV firms. Despite the uncertain prospect[126], these PV firms continued to invest heavily in capacity expansion of their current c-Si platform. The "competence hypothesis" concept illustrates that these firms would still prefer to bet on the area of their perceived competence – the manufacturing of their domain technology – despite their knowledge of the presence of uncertainty and the prospect of a low probability of gain (Fox & Tversky, 2000; Heath & Tversky, 1991; Tversky & Fox, 2000).

Narrow framing, prevailing frames and conditions for the prediction

The second observation from the framing of the external environment regards *the narrow framing in assessing the choices and attributing the causes of the decision*

[125] There are other factors such as industry dynamics involved; details are discussed in Chapter 4.
[126] For example, the overcapacity of c-Si cell and modules, and the changing value proposition in the supply chain; as discussed in Chapter 4.

problem. Specifically, the tendency to rely on over-optimistic market forecasts and to attribute the decision problem of new capability investments as institutional resource issues are both found among the case firms. The insight of this observation lies in that it calls for re-examining the common view of regarding the resources constraint in the institutional environment as the root cause for limiting the firms' new capabilities investments.

The third observation from the empirical investigations of Chapter 4 regards *the prevailing decision frame* in capability investments among decision makers. Firstly, the decision frame of "loss aversion" has been commonly illustrated in the decision task of exploratory investments, which is also observed in the empirical Chapter 4. The focus of Chapter 4 then moves to another prevailing frame at the institutional level: the common mind-set of national competitive advantage. This research suggests that as this prevailing thought encourages the exploitation of current competitiveness, it may impede investment in developing new capabilities.

Therefore, in illustrating the prevalence of narrow framing, this research extends the concept of the "passive acceptance of a decision frame" from the experimental environment to real-world business settings, and addresses the influences of industrial and institutional environments. The observation of the prevailing frame in the institutional environment appears to be similar to the notion of institutional logic (Thornton & Ocasio, 1999). Yet this research departs from the institutional school in that it emphasizes psychological mechanisms such as association and availability in the heuristic judgment process, rather than the social mechanism of imitation, or of following the norm (DiMaggio & Powell, 1983).

The conditions for the prediction of narrow framing and the prevalence of the decision frame lie in *the presence and relevance of successful experience* in the investigated decision context, which is specifically applied to the phenomenon of the prevailing frame of adaptation. This research suggests that the prevailing frame can be identified by the availability of best practice in the industry itself, or in related industries in the same institutional environment. Further, the relevance of the experience can be evaluated through the characteristics of the technology employed in the industry. For example, although the PV industry is characterized as an emerging industry, its c-Si PV cell manufacturing and management processes are closely related to semiconductor technologies, in which competence has already been established in the Taiwanese institutional environment.

Differentiated framing (selective attention)

As shown in the empirical investigation in Chapter 5 and Chapter 6, differentiated framing, or referring to selective attention, does exist at both firm and decision maker levels. The findings suggest that such a difference in framing does not necessarily lead to different choice pattern. Chapter 5 demonstrates that at the firm level, the pattern of selective attention can be influenced by firms' resources, ownership or CEO's experience. But such differentiated framing does not necessarily lead to differences in the capability investment pattern.

In examining differentiated framing at senior manager level, the finding from Chapter 6 shows that while professional experience may affect the attention focus on short-term market signal; it is less relevant than organizational influence in framing long-term prospect. Beyond the mechanism of organizational identification proposed

by organizational scholars (March & Simon, 1958; Simon, 1996a), this finding illustrates that decision makers may use different frames in the framing process. Specifically, here one of the decision frames can be defined as the decision makers' professional experience; the other decision frame refers to the organization's decision problem (such as its resources or competitive position within the industry). This concept of the relative influence of the decision frames corresponds with the "perceptual filter" proposed by organization scholars (Starbuck & Milliken, 1988). Here this research advances the argument that in terms of framing future development, the background filter that is defined as the individual's expertise can be less influential than the foreground filter of the organization's decision frame. In Chapter 6, the observation of senior managers' selective attention influenced by a corporate frame is consistent with the finding of selective attention of responding strategies at the firm- level investigation of Chapter 5. But again, the question is whether such differentiated framing is relevant in the decision to invest in new capabilities for the future.

The moment-based experience effect vs. the accumulated experience effect

The above discussion of the role of framing and frames in the decision process points to the influence of experience. The experience effect plays a central role in the psychological mechanism proposed by behavioural decision scholars. While the behavioural decision school initially focused on the heuristic judgment process, scholars' pursuit of the experience effect in the judgment and decision process has revealed a later divergence of focus. In fact, Kahneman and Tversky emphasize different temporal effects of experience on the framing of the decision. Kahneman proposes the "moment-based" experience, with the focus on unpredictable preferences

for future events, while Tversky takes a long-term view on the "accumulated" experience effect which appears to be close to the notion of path-dependency (Kahneman, 2000a). While the two views are similarly constructed using the basis of heuristic judgment in the framing process, different psychological effects are highlighted: the accumulated experience effect addresses the feeling of control; the moment-based effect focuses more on the immediate perceptual experience of losses and gains[127]. Therefore, while the moment-based effect emphasizes the general pattern of ad-hoc attribute substitution in the judgment process, the accumulated effect takes into account the specific background of the decision makers[128].

This research argues that both long and short-term views of the experience effect can be consolidated in order to elaborate the role of framing in influencing the decision of capability investments. While behavioural scholars have not further pursued the settling of differences between the two views (Kahneman, 2000b), this research demonstrates the reconciliation of the two views in applying these concepts to a business setting. Firstly, the long-term view of accumulated effect helps to identify the potential dominant frame. The prediction would be based on the relevance of past experience. Particularly in this research, the accumulated view explains the competence effect and the prevailing frame. Secondly, the short-term view of moment-based effects permits the possibility of altering the perspectives and unpredictability of future preferences in the judgment process. The prediction would be based on the experience of changes compared with the status quo or the expectation level. In this research, the moment-based view is particularly illustrated in the diminishing sensitivity to uncertainty. With the emphasis on changeable

[127] Kahneman also refers to the moment-based view as the "hedonic" experience.
[128] For example, in his later research, Tversky examines the role of belief in influencing judgment under uncertainty.

preferences in the judgment and decision process, this moment-based view further implies the reality that decision makers may use different frames in the framing process, as pointed out in this research.

How does the role of framing matter?

This research suggests a two-fold problem of framing in the judgment and decision process of capability investments. The first problem is the *excessive reliance on experience*. Applying the availability and representative heuristics, decision makers tend to attribute and justify the causes of the decision problem based on the association of their experience in the decision context. This experience-steered judgment is reinforced by the role of belief derived from accumulated experience in the specific area. The second problem is that of *insufficient adjustment.* In this research, there are two observations similar to the concept of the anchoring heuristic. Firstly, decision makers may set the wrong target and reference (although they are not assigned with a specific anchor, as in the experiment). Secondly, even they can notice the correct target and trend, the associated adjustment is still not sufficient to cope with change, especially the downward influence of the external environment.

This two-fold problem leads to the phenomenon of the prevailing adaptation frame. From the perspective of evaluating the decision outcome, this decision frame does not necessarily appear to be inferior during the context-dependent assessments over different time periods. The prevalence of the adaptation frame seems to be inevitable, as it is easier to be sustained throughout short-term focused market trading and the corporate management mechanism. However, the problem with the adaptation frame is not only that it tends to favour exploitation, but also that it may prohibit alterative

frames in the judgment and decision process.

Therefore, in respect to “framing”, the problem is associated with heuristic biases, whereas in respect to “frames”, the problem lies in perspective biases. To deal with the “framing” problem, the behavioural decision school generally proposes the prescription of the controlled System 2 processes to override the automatic System 1 heuristic judgments. To deal with the problem of the persistence of a particular decision frame, more emphasis appears to be placed on the manipulation of external influences. From this perspective, the organizational decision school provides the better prescription based on the organizational mechanism. The concepts of “deliberation” and “program” in these two prescriptions lead us to the discussion of the role of deliberate practice.

The role of deliberate practice

The investigation of deliberate practice is motivated by the findings of the loosely coupled framing and choices in Chapter 5 and Chapter 6. As discussed, the differences of framing at firm level and at senior manager level are not evidently linked to differentiated choice patterns. The common view of management cognition studies usually links the framing of future prospects and competitive position to the firm’s strategic actions. But the findings of this research suggest that such framing is not necessarily relevant to the decision to explore opportunities through investing in new capabilities.

This research argues that the potential role of deliberate practice may explain the behaviour of exploration. In the context of narrow framing in favour of exploitation,

the prescription from the behavioural decision school points to utilizing deliberate heuristics from the controlled System 2. In this research, the application of option logic in evaluating new investment projects is an example of this. The case firm of *Greenchild* seems to fit this recommendation. Yet the findings show that *Greenchild* only exhibits a simple option approach toward exploratory projects on the condition of government funding, and that there is no evidence that such specific practice is established on the awareness of deliberately applying the option heuristic in the evaluation of capability investments. Further, the firm did not evidently follow the rigid real options approach in analysing the investment options. The fact that the case of *Greenchild* is not a perfect fit for rationality logic and the real options approach actually distinguishes the application of rational decision model for strategic analysis from the concept of deliberate practice.

Deliberation vs. mechanism

This research suggests two approaches for deliberate practice that are specifically designed for exploratory investments. They incorporate prescriptions from both the behavioural and organizational decision perspectives, but with some refined suggestions. The first is to *develop the low-level procedural program.* Here the term "low-level" refers to the implementation level of the rationality procedure to differentiate high-level coherence in the application of the rational decision model. At first sight, this proposition seems to contradict the suggestion from the behavioural decision perspective in which the accuracy of judgments and decisions is stressed. The point here is that while the behavioural decision scholars illustrate the incoherence in the assumptions of rational decision models, adopting the more demanding rationality standard for judgments can be just too difficult in real-life

decision context settings. For example, option thinking logic can be easy to apply to the concept of experimentation for exploratory investments. But the concept of framing the capability investment as options in market tests, and the approach of following the assessment in the real options model can be too complicated in the practical sense. In fact, from the standpoint of "practice", the emphasis of procedural rationality in this proposition is still in line with the prescription of activating the deliberated System 2 process.

The second approach is to *provide the separate evaluation and implementation mechanism.* This prescription addresses the concept of the specially designed mechanism (with separate measurements) to facilitate experimentation for exploratory investments. Here the proposal is to suggest a stronger form of separate mechanism such as an external partnership mode[129], rather than the concept of organizational slack, which embeds the mechanism inside the organization. From the organizational perspective, the external partnership structure is a convenient design for separating evaluation and implementation from the existing organizational decision routine, which is inclined to favour exploitation and the pursuit of immediate business goals. From the behavioural decision perspective, the benefit of external partnership lies in providing an outsider viewpoint, and the potential to develop alternative frames. In this sense, this proposition implies that the mechanism for exploration may be better situated at least partially outside of the organization.

[129] Corporate venture can be regarded as another mode of the separate evaluation and implementation mechanism outside of the organization.

7.3 Implications, limitations and future research

This research contributes towards understanding how firms respond to uncertainty, and what factors influence their decisions regarding capability investments. In addressing the debates on rationality assumption and the interaction of influences in the decision context, this research provides implications from two perspectives: one is the application of rational decision models, and the other is the triggering mechanism for exploration.

Implication: the application of the rational decision model

It is a common view that accumulated experience may generate the lock-in effect, but here a specific phenomenon of reliance upon experience refers to the influence of established rational decision analysis. The implications of this research suggest that rational decision analysis may not necessarily explain actual decision behaviour, and that sometimes the assumed rationality analysis may constrain judgments in the context of uncertainty. The reason is that usually a certain (biased) perspective that has been influenced by experience has already been put into place before the normative framework of rational decision analysis is applied. It is argued that the psychological phenomenon of “cognitive dissonance” seems to be inevitable in the process of rationalizing the connection between cognition and decisions (Festinger, 1962), and therefore rational models are usually suited (and utilized) to justify decision behaviour (March, 1994, 2008). Two examples of this are the strategic applications of the environmental analysis of opportunities/threats, and the competence analysis of competitive advantages, which are well known among managers with business educations.

The problem with the rational decision analysis is not necessarily the model itself, but rather the implicit assumptions that are made when applying these decision models. Therefore, there is a two-fold implication from the standpoint of the firm and the third-party stakeholders such as analysts, academics and policy makers: for the latter, the recommendation is to incorporate the descriptive decision analysis to supplement the rational model in explaining and predicting the firm's behaviour; for the former, the suggestion is that the rational decision model can still be a useful tool for structuring thinking and procedure in the decision process. Organizational scholars describe "simple low dimensional representation" (Levinthal, 2011:1520) and "strategic heuristics" as the simplification of deductive reasoning logic suggested in the strategic framework (Kogut, 2008; Levinthal, 2011). The application of the rational approach views "rationality as a process not as an outcome" (Levinthal, 2011: 1522; March, 1994). Here, it further suggests that the caveat is to re-examine both assumptions that have been taken for granted, and the underlying logic derived from experience-steered judgements.

Implication: the triggering mechanism

Firstly**,** the implication of this research suggests that despite the inevitable and constraining role of framing in the judgment and decision process, such process could be improved through deliberate practice. In this research the concept of deliberate practice is not entirely the same as in the expertise research[130]. Also, the idea that deliberate practice could improve performance particularly refers to the activation of

[130] In the expertise research, the acquisition of expertise is through deliberate practice. In this research," deliberate practice" refers to the utilization of the controlled System 2 process, not the activity of acquiring the expertise in a specific domain.

the deliberate System 2 and the improvement of the thinking process[131], not necessarily a direct link with the performance of a specific decision outcome.

Secondly, the implication of this research suggests that despite the individuals' potential to improve the thinking process, certain individuals' attributes are not necessarily linked with the mechanism for exploration in the organization. Compared to individuals, the organizational mechanism can more reliably serve as the driver for exploration and change. I suggest two recommendations for the design of the deliberate mechanism: the first is that the design of the procedural program should be based on simple principle rather than tied to the details of the firm's idiosyncratic attribute. The idea is that since it is designed as a separate mechanism for exploration, deliberate practice as procedural rationality will not necessarily be restricted by the firm's current state in terms of size and resources[132]. However, considering the reality of implementation and potential heuristics biases, the second recommendation implies that sometimes it could be more effective to let action rather than thinking drive the mechanism for exploration in the organization (March, 1994), for example by leveraging external resources through collaborating with partners in implementing the deliberate mechanism for exploration. It is useful not only in terms of extra resource support (because investing in such mechanisms can be costly for the firm), but also in terms of helping to initiate and sustain the development of new ideas outside of the firm's boundary of capabilities and the framing of opportunities.

[131] The improvement of thinking processes is easily measured by the "decision performance" in the behavioural experiments. But in this research, there is no empirical evidence on the improvement of the thinking process. The expected improvement of "performance" on System 2 process is based on the proposition drawing on behavioural decision theory.

[132] In the expertise research, the resource constraint is suggested as one of the factors influencing the deliberate practice. In this research, both the case firm *Greenchild* and *Amorphou*s were able to leverage government funding support.

Thirdly the implication of this research suggests that there are certain systematic patterns based on the assessment of heuristic judgment. To some extent, such patterns of response to environmental uncertainty could be predictable (although not necessarily in the expected direction as predicted by the rational decision analysis), particularly if the "experience effect"[133] is placed at the centre of the analysis. From the standpoint of policy analysis or design, the first suggestion is to consider the perception of the change effect compared to the status quo, or the expectation level in influencing the anticipated result of a policy measure. In addition to the experience effect of diminishing sensitivity to policy uncertainty (as discussed earlier), another example is the reverse effect of incentive reduction in the PV industry. One of the goals in reducing the government incentive program was to aim at balancing supply and demand. However, the case showed that the announcement of the policy change induced a large amount of production and deployment in a short period of time, which was influenced by the expectation of grabbing larger gains before the anticipated incentive cut in the near future. The second suggestion is to consider the effect of persistent ideology in the institutional (in a national context) environment. While the prevailing thought may not be easy to change, one feasible way is to not necessarily focus on high-level theoretical debate, but rather address the low-level practice in implementation. For example, rather than debating whether or not there should be a top-down national technology policy to drive the development of certain competitive advantages, maybe a better practical solution would be to focus more on the design of the policy program for promoting exploratory investment.

Limitations and future research

[133] See the discussion of the moment-based and accumulated experience effect in Section 7.2.

Firstly, the narrow framing effect observed in this research seems to be closely related to a specific industrial and national context. Indeed, there are two phenomena which are specific to the PV industry and to Taiwan. The first is that of policy uncertainty. The influence of policy-regulated demand may not be easily found in other industries, yet it can be generally applied in the renewable industry sector. The fast-paced change in policies and the co-evolved industry dynamics makes the PV industry a good case to illustrate both industrial transition and firms' responses to uncertainty. The second is in the characteristics of PV technology. The similarity with semiconductor technology in terms of manufacturing know-how appears to demonstrate that Taiwan is a specific case. Such a phenomenon may not necessarily be observed in other institutional environments. However, it is the objective of this research to examine the influence of the legacy effect in industrial and institutional contexts. Rather than viewing the two industry-related phenomena as limitations, the investigation of this specific decision context identifies and highlights conditions for the prediction of narrow framing and the prevailing frame. Therefore, future research could further examine proposed conditions of the uncertainty pattern and the experience effect in other industries, or institutional settings.

Secondly, the limitation of this research may lie more in the organizational decision complex, in which the collective decision behaviour of multiple actors and the social influence of power and politics could be involved in the decision process. But the topic of group decision dynamics is another research area, and is not the objective of this research. In fact, this research emphasizes the interviewee's representativeness of their firm's decision behaviour in order to moderate the potential group decision effect in the investigation. According to their position within the organization, the chosen interviewees (especially senior R&D managers) are the final decision makers in the

functional department in their firms. Additionally, the choice of selecting functional heads rather than CEOs is made on the grounds that the investigation of these senior managers may better reflect the process of interpreting the decision problem and actions at a practical level. As this research emphasizes the issue of functional expertise at an individual level, future research could look into the influence of expertise on the framing effect in the context of group decision dynamics.

The third limitation is related to the investigation of deliberate practice. In fact, this topic emerges later in the process of examining the role of framing in the decision process for capability investments. There are two issues: the first one is the lack of direct observation of the decision routines regarding investment decisions in these case firms[134]. The second is that given the nature of the decisions (critical, and business related), direct observation[135] of the process is just too difficult to put into practice. While the validity of the findings in this research is still solid based on the evidence and information sources, a different research design and methodology for investigating the role of deliberate practice and decision routines could be developed in the future.

Drawing from the concepts of the System 1 and System 2 process, procedural rationalities and decision routines, this research proposes a deliberate mechanism designed for exploration. This proposition would require further empirical examination, and could signify a promising area of future research in the interests of both practitioner and academia. In addition, future research could look into the

[134] The empirical findings of deliberate practice in this research are based on interviews with the firm's senior managers and third-party interviewees as well as archival data sources.
[135] Here, direct observation refers to the researcher being physically able to observe the decision-making process.

relationship between organizational structural factors and deliberate decision practice. Further studies could also compare deliberate mechanisms implemented outside of the firm (e.g. collaborations with partners) to those that exist within the organization.

Finally, a related area of future research is the link between the decision procedure and the decision performance. In fact, the measurement and assessment of the decision performance is another research topic. While this research stresses how the deliberate mechanism – rather than the role of framing – explains the behaviour of exploration, it does not make a direct connection between the deliberate decision practice and the decision performance. From the standpoint of organizational design, the argument for the deliberate mechanism is based on two concepts: the first is the procedural and the substantial program. In this research, the substantial program rather than the procedural program is related to the decision performance. Thus although the idea of procedural rationality aims at improving the decision process, it does not necessarily offer the guarantee of a superior decision outcome (performance). The second is the separation of the mechanism for exploration from the existing decision routine. In this research, the idea refers to that the link between the exploratory investment and the evaluation of the decision outcome (something that is usually linked to short-term business performance) is purposefully weakened in order to sustain the deliberate mechanism within the organization.

As discussed, the investigation of the relationship between the decision procedure and the decision performance is not the objective of this research. Yet the proposition of deliberate practice does imply that the chances of better decision outcomes can be increased, as the design of such mechanisms is to overcome potential biases in the judgment and decision process. The question of whether, and to what degree, decision

procedure leads towards better decision performance is one of the central themes in strategic research. The topic of how deliberate practice can enhance strategic thinking and the relationship with the expected decision performance would be an interesting area for further study that could be extended from this research.

Glossary of Acronyms

a-Si	Amorphous Silicon
ASP	Average Selling Price
BIPV	Building- Integrated Photovoltaic
BOD	Board of Director
BOS	Balance of System
CdTe	Cadmium Telluride
CIGS	Copper Indium Gallium Selenide
CPV	Concentrator Photovoltaic
CSO	Chief Strategy Officer
c-Si	Crystalline Silicon
CTO	Chief Technology Officer
CZTS	Copper Zinc Tin Sulfide
DSSC	Dye-sensitized solar cell
EPC	Engineering Procurement and Construction
EPS	Earnings Per Share
FIT	Feed-in-Tariff
GM	General Manager
IPC	International Patent Classification
ITRI	Industrial Technology Research Institute
JV	Joint Venture
LCOE	Levelized Cost of Electricity
LTS	Letter to Shareholders
MOEA	Ministry of Economic Affairs
MW	Megawatt
NGO	Non Government Organization
NREL	National Renewable Energy Laboratory
PV	Photovoltaic
ROI	Return on Investment
TF	Thin Film
VC	Venture Capitalist

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